1980 C.B. ANNUAL REPORT

VOLUME 2

ENVIRONMENTAL ANALYSIS

CATHEDRAL BLUFFS SHALE OIL COMPANY

TENNECO SHALE OIL COMPANY

OCCIDENTAL OIL SHALE INC., OPERATOR

751 HORIZON COURT

GRAND JUNCTION, COLORADO 81501

APRIL 30, 1981

1980 C.B. ANNUAL REPORT

VOLUME 2

ENVIRONMENTAL ANALYSIS

April 30, 1981

Submitted by:

CATHEDRAL BLUFFS SHALE OIL COMPANY
TENNECO SHALE OIL COMPANY
OCCIDENTAL OIL SHALE, INC., OPERATOR
751 Horizon Court
Grand Junction, Colorado 81501

to:

Mr. Peter A. Rutledge
Deputy Conservation Manager
Oil Shale Office
Conservation Division
U.S. Geological Survey
Grand Junction, Colorado 81501

FOREWORD

The 1980 C.B. ANNUAL REPORT is submitted to fulfill the requirements of Oil Shale Lease Number C-20341 as stated in Section 16(b) of the Lease, Section 1.(C)(4) of the Lease Environmental Stipulations, and Condition of Approval (No. 3) of the Detailed Development Plan issued on August 30, 1977. This report consists of the following volumes:

Volume 1 - Summary of Development Activities, Costs and Environmental Monitoring

Volume 2 - Environmental Analysis

Appendix 2A - Volume 2 Supporting Data

TABLE OF CONTENTS

1980 C.B. Annual Report

Volume 2 - Environmental Analysis

Page No.

LIST OF FIGURES

List of Figures - Continued

LIST OF TABLES

List of Tables - Continued

List of Tables - Continued

List of Tables - Continued

1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

The Environmental Baseline Period for Oil Shale Tract C-b covered the period from November 1, 1974, to October 31, 1976. Results have been reported in nine Quarterly Data Reports, eight Quarterly Summary Reports, C-b Annual Summary and Trends Report (1976), and a 5-volume Environmental Baseline Program Final Report (1977), all submitted to the Oil Shale Supervisor.

From November 1, 1976 through August 31, 1977, the C-b Tract was under a period of suspension of the Federal Oil Shale Lease. The monitoring conducted during this period was executed under a program known as the Interim Monitoring Phase. Environmental data for this time period were submitted to the Oil Shale Office (OSO) on October 14, 1977 (Interim Monitoring Report #1). The Interim Monitoring Period was later extended by the OSO to cover the period from September 1, 1977 through March 31, 1978. Data for this time period were submitted to the OSO on May 15, 1978 (Interim Monitoring Report #2). The Development Monitoring Program was initiated in April 1978. The Development Monitoring Program for Oil Shale Tract C-b was submitted to the OSO in a document dated February 23, 1979 and approved by the OSO on April 13, 1979 subject to 13 Conditions of Approval contained in that approval letter. Semiannual environmental data reports are submitted every January 15 and July 15.

The Interim Monitoring and Development Monitoring Programs have been reduced and changed from the Environmental Baseline Monitoring Program in many areas. Therefore, emphasis is now placed on key indicators of environmental quality and/or change. The 1980 C.B. Annual Report, Volume 2 provides detailed data analysis as in 1979. This summary is essentially the same in both Volumes 1 and 2.

The purpose of this report is to fulfill the requirement of the lease to provide the Oil Shale Supervisor's Office with an annual report of environmental analyses. The Development Monitoring Plan states the following objectives with respect to environmental monitoring:

> The purposes or objectives of environmental monitoring as defined in Section 1 (C) of the Stipulations are to provide: (1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data, (2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State and local environmental protection and pollution control requirements, (3) timely notice of detrimental effects and conditions requiring correction, and (4) factual basis for revision or amendment of the Stipulations.

Volume 2 documents the analyses and conclusions relative to assessment of potential environmental impacts and trends that may be indicated in the collected data. Since development activities were not started until 1978, much of the data and analyses may be considered as a continuation of environmental baseline and background definition.

1.2 Summary

Environmental monitoring and analyses are continuing on Tract C-b. Development activities commenced within the past three years have resulted in increased activity on the Tract in the form of off-road vehicular use, facility construction, shaft sinking, and traffic into and out of the area. All activity has been conducted within strict adherence to environmental, permit, and lease regulations. Environmental impacts, where they exist, have been confined to the immediate area and within limits defined in the Detailed Development Plan.

1.2.1 Indicator Variables

The Development Monitoring Program has been brought into sharper focus with the identification of Class 1 indicator variables. These are key environmental variables collected at representative stations in at least monthly sampling frequency. Time series plots, generated by the computer from the data base and all to a common time scale, are updated in the semiannual data reports to provide visual analyses of trends and interrelationships. As a statistical screening process, linear short- and long-term trends have been examined at a five percent level of significance for air and water and to 20 percent for biology; results are discussed in the respective chapters.

1.2.2 Tract Imagery

A photographic record of Tract changes has been continued through 1980 as in previous years. A 360° horizontal pan is photographed in color on a yearly basis at 35 photo points. From an aircraft overflight an aerial mosaic has been prepared (Figure 4-1 of Volume 1). Color infrared panoramic photographs of the vegetation around springs and seeps were obtained twice during the growth season.

Landsat digital imagery was used as in previous years to monitor vegetative condition in the Tract vicinity. A new data filtering algorithm was tested and shown to be effective in change detection within and between years, based on a normalized reflectance difference index. Data from 1980 imagery were used to further refine the calibration curve of biomass vs. the normalized index in the pinyon-juniper and irrigated meadow vegetation types. During 1980, the image analysis software was acquired by the C.B. project so that the imagery techniques could be routinely used.

Image analysis showed that biomass in June 1977 was less than in 1980 in selected areas (Table 4.2.5-1). Climatological data show that 1977 was a drought year, and 1980 above normal in moisture. Increases in biomass within the growing season are also identifiable from the imagery. Increases in disturbed acreages were shown through the years as development proceeded.

1.2.3 Hydrology

A development monitoring program has been implemented to provide water quantity and quality data for the purpose of impact evaluation. Streams, springs, seeps, alluvial and bedrock aquifers, shafts and impoundments are presently monitored. The monitoring station locations are shown in Figures

5.2.1-1, 5.2.2-1, 5.2.3-1 and 5.2.4-1. The present hydrologic monitoring network has been expanded over that which existed during the baseline period to comply with new requirements under the Water Augmentation Plan and Consent Decree as implemented in August, 1979.

Baseline studies indicated the mean flow for the reach of Piceance Creek adjacent to the Tract to be approximately 15 cfs. Records since then indicate no significant change in mean annual flows. One-day minimum flows there have reached less than 1 cfs. Maximum daily flows upstream and downstream of the Tract were measured as follows:

	Upstream (Sta 007)	Downstream (Sta 061)
Previous Daily Maximum (cfs)	157 (May '79)	149 (May '79)
1980 Maximum (cfs)	135 (May '80)	133 (May '80)

No significant trends in streamflow are apparent.

Short-term linear correlations between precipitation at C-b meteorology stations and flow from springs are not apparent. This would imply that events that occur on the surface of the Tract do not have a major effect on flow in the springs. There are no long-term, linear trends over time as shown by general linear modeling. General linear modeling indicates a trend for average monthly flow over the past year. The slope of each regression line is small (none are greater than 0.003 cfs/mo). Of ten springs, five show positive slope and five show negative slope. Considering these analyses, at the present time it appears that there is no effect of development activities on spring flow.

On a short-term basis, the linear model fits none of the alluvial well data. There are some long-term trends exhibiting a slightly negative slope, however these negative slopes began during baseline for some wells. Most importantly, there does not appear to be any effect of dewatering on the water of the alluvium of Piceance Creek.

Dewatering continued during 1980 and levels in wells near the shafts continued to decline. Of the C-b Tract wells, the only water level which did not decline was in WX10 and, in fact, its water level increased. The largest water level declines occurred in those wells closest to the shafts. There was a decrease of 160 feet in the water level at WX33 near the V/E Shaft. WX32 near the Service/Production shafts dropped about 275 feet. Declines elsewhere on the tract varied from four feet in WX17 in the southeast corner to about 70 feet in WX02 near the north boundary of the Tract between Sorghum and Cottonwood Gulches.

Off-Tract wells and water augmentation wells showed declines based on proximity to the shafts. WX21, located south of the tract on Scandard Gulch, began declining very slightly late in the water year, with a total decline of about two feet. Wells WX19 and WX20 are both about one-half mile north of the Tract. A decline of about 55 feet was recorded in WX19, and the water level in WX20 dropped about 90 feet.

Remote off-Tract wells showed no declines in water levels. Some wells, for example, WX67, WX72, WX64, showed slight rises in water levels on the order of one foot. WX73 and WX75 showed no changes.

Table 5.2.4-2 summarizes water level changes in upper aquifer wells at C-b Tract. Figure 5.2.4-8 summarizes the changes in water levels between October 1979 and September 1980. Values have been linearly interpolated from the well locations shown therefore the plot should be considered tentative. The amount of drawdown decreases with distance from the shafts. The effects of drawdown were not significant at distances greater than two miles from the shafts.

Hydrogeological data as fracture measurements, structural data, and rock quality data were obtained in all the shafts. In addition the hydrological data related total shaft inflows during sinking, effects on the groundwater monitoring well levels, and physical mapping of zones which produced water.

Water quality data for stations upstream and downstream from the Tract on Piceance Creek, and for stations in Stewart and Scandard Gulches are summarized on Table 5.3.1-5 by comparison with baseline. Ratios of 12-month means for WU61 and WU07 are shown in Table 5.3.1-6. During 1980, discharges were made under the NPDES permit and Station WU42 measured water quality affected by these discharges. Increases in concentrations at WU42 were concomitant with discharge timing and amounts, but differences in concentrations upstream and downstream in Piceance Creek were not marked except for ammonia, which was attributed primarily to livestock operations although mine-water seepage monitoring wells in 1980 are also higher in ammonia (Table 5.3.6-5). There was no change in fluoride on an annual average basis. At the four major USGS stations, linear trends were shown for arsenic at WU07 with a very slight positive slope, and for dissolved organic carbon at WU22. Dissolved oxygen showed very slight negative slopes at WU22, WU58, and WU61 that may have been temperature dependent.

Water quality data from springs show few trends with time, except for arsenic which shows a negative slope in the linear regression with time. Specific conductivity data show consistent means and standard deviations indicative of a possible common source. Specific conductivity values are also much lower for springs than for wells or surface streams indicating the probability that the springs may be precipiation derived. Baseline data for fluoride are two to three times greater than subsequent values implying that fluoride as well as arsenic concentrations are decreasing.

Alluvial well water quality data showed negative linear trends with time for some wells or showed no trends at all in others.

Upper Aquifer water quality showed little change. Regression line slopes were either very slightly positive or negative. All were very near zero except TDS at WX10 which showed a significant negative slope. Linear trends in Lower Aquifer data were essentially zero except for a slight negative slope in magnesium at WY51.

Seepage monitoring wells show some effects of impoundments and these data are summarized in Table 5.3.6-5. Data before impoundment, however, are based on only four samples. General trends in the V/E shaft water quality may be summarized as follows. The general trend in the "A" Groove is that values increase with depth. From the base of the Uinta to the base of the Four Senators, values of TDS and NO_3 are constant with depth except for one high value for NO_3. Values of NH_3 decreased with depth and values of B increased with depth. In the Upper Parachute Creek above the A groove, values of TDS and Na increase with depth, while values of NH_3 increase irregularly with depth. Values of NO_3 and F are constant within a narrow range of values. Values for SO_4 are very irregular and have no trend. In the Mahogany Zone values of TDS, SO_4, and Na increase with depth to about 5,390 feet and then decrease with depth. Values for NO_3 and Cl are constant. Values for NH_3 and B have an irregular profile when plotted against depth with NH_3 irregularly increasing with depth and B irregularly decreasing with depth. Values of F are also irregular with maximum values in the lower (deeper) zone.

1.2.4 Aquatic Ecology

Benthos and periphyton data were obtained and analyzed in 1980. The analysis of the periphyton data at present does not show any effect that may be attributable to Tract operations. Although statistical analysis does show significant differences between stations and months, no trend relating these differences to the control stations versus the two test stations was established. The variability in the data indicated by statistical analysis is deemed to be due to natural causes.

1.2.5 Air Quality

Figure 6.2.1-1 shows the air quality monitoring network. Compliance with State and Federal air quality standards continued to be maintained at the C-b site during 1980. Concentrations in 1980 were monitored at levels far below the appropriate standards as shown in Table 6.2.1-5. High particulate values in 1974 were due to fugitive dust. Results of a linear time-trend analysis are shown on Table 6.2.1-4. Negative trends in carbon monoxide concentrations were indicated at both 020 and 023 for both short- and long-term data. Short-term represents 1980 data; long term represents data since baseline. Linear trends indicated for the other pollutants are accompanied by regression line slopes of essentially zero. That is, there are no significant trends in air quality due to development. Table 6.2.1-6 shows the maxima, means, and ratios of maximum-to- mean concentrations of gaseous and particulate constituents at stations AB20 and AB23 for 1980.

Mean visual range for Spring 1980 was 78 miles, compared to a previous spring average over 1976-1979 of 72 miles. For Fall 1980 the average was 85 miles compared to that over 1976-1979 of 82 miles.

1.2.6 Meteorology

Figure 6.3.1-1 shows the climatological network.

Meteorological data gathered during 1980 showed that monthly mean and variations in temperature are consistent with the values from the past five years since baseline. A new maximum growing season length of 151 days from 12 May to 15 October was established during 1980. Solar radiation remained in normal range and relative humidity measurements are consistent. Precipitation in 1980 was variable from month to month with annual totals of 35 cm at AB20 and 27 cm at AB23. Differences in the amounts recorded at the two stations are a result of the spatial variability that is typical in the region.

1.2.7 Noise

Monthly peaks in traffic noise levels and background levels during development exceed baseline levels by approximately nine dBA. Increased noise is due to development activities. These activities have produced noise levels on-Tract that are generally low (approximately 44 dBA average) and well below State noise standards for an industrial zone.

1.2.8 Wildlife Biology

Figure 8.7.2-1 presents the biological network also showing areas of the land application system.

Deer pellet group densities were higher in 1979 and 1980 than in 1978 and 1979. Deer migrational movements and distribution along the highway have remained the same over the years. The 1980 high count was 1409 and occurred in April. Deer mortality was higher in 1979-1980 than in the previous years 1977-1979. Fawn counts were lower in 1980 than in 1979.

Road kills vary in numbers over the years. Road kills appear to be dependent upon herd size and traffic density, although more data are required to adequately define the relationship.

Bitterbrush utilization by deer was lower in 1980 than in 1979, and is not significantly affected by C-b development.

No significant trends in coyote abundance were apparent in 1980.

Lagomorph populations are not significantly affected by C-b developments and no significant difference has been detected in preference between chained rangeland and pinyon-juniper habitats.

Small mammal populations were sampled in the areas where sprinkler irrigation occurred and control areas, and the results compared. Deer mice avoided the watered areas, while golden-mantled ground squirrels preferred them. Trapping results for habitat preference are similar to past years. The least chipmunk prefers chained rangeland while Uinta chipmunk prefers pinyon-juniper habitat.

No significant changes in songbird densities have occurred due to C-b development. Mourning dove populations fluctuate from year to year and

show no apparent effects of development. Raptor populations appear stable and the number of nesting sites show no apparent effect due to C-b development.

1.2.9 Vegetation

Bitterbrush production was lower than in 1979. No major changes have occurred in the herbaceous layer components in either the upland or bottomland sagebrush shrubland types. Even though the exclosures have been in place for six growing seasons, the open and fenced plots still share a high degree of similarity. Shrub species composition has remained essentially the same. These small changes that appear seem to be related to natural variation or sampling error and do not appear to be related to oil shale development on the site.

1.2.10 Ecosystem Interrelationships

Ecosystem interrelationship studies have been continued as a means of assessing the potential impact of environmental perturbations resulting from development activity. Quantitative studies to date include the effects of climatic variations on herbaceous productivity and effects of traffic, climate, and size of mule-deer herd on deer road-kill. Previously established linear results that still hold are as follows: (1) herbaceous productivity correlated best with precipitation in April-May-June and total precipitation of the previous year, and (2) deer road-kill correlated best with deer road-count.

1.2.11 Items of Aesthetic, Historic, or Scientific Interest

Surface activity was somewhat limited at the site in 1980 as in 1979. A concerted effort has been made to paint and locate new structures to reduce any aesthetic impact. Additionally, the on-site environmental staff has thoroughly investigated every site of disturbance and no additional historic or scientific discoveries have been made.

1.2.12 Health and Safety

Accident frequency analyses and inspection reports (Mine Safety and Health Administration and Colorado Division of Mines) are included in the Development Monitoring Plan and its reports. At C-b based on 783,871 man-hours, there were 15 lost-time accidents. The site injury rate in 1980 was 5.10 (incidents/200,000 man-hours). This compared with five lost-time accidents in 1979, and an injury rate of 1.91.

1.2.13 Toxicology

Oil shale materials have been tested carefully by several research laboratories (Kettering Laboratories, University of Cincinnati; Bio-Research Consultants, Inc., Cambridge, Massachusetts; and Eppley Institute for Research in Cancer and Allied Diseases, Omaha, Nebraska) on behalf of private companies developing oil shale and at the request of the American Petroleum Institute. Detailed chemical analyses were done to measure the presence of known or potential cancer-causing substances in oil shale rock, crude shale oil and other products made from it, the rock residue left over after processing, and the air

emissions from equipment during processing. In addition, experiments were conducted with mice and hamsters to determine if concentrations of such materials or extracts made from them are hazardous.

Raw and processed oil-shale rock have not shown carcinogenic characteristics in these tests. Liquid shale oil has been shown to produce skin cancer in mice as have certain uniquely processed petroleum products from conventional crude oil. Therefore, normal care must be taken to protect workers from potential carcinogenic effects.

When shale oil is upgraded, however, its carcinogenic potential is reduced. And, since these problems have been dealt with for many years in the industry we are convinced they are manageable. In addition, the amount of BaP (a natural substance which is known to cause cancer in animals and is suspected of being able to cause cancer in humans) is greater in numerous common materials such as soil, fruit, oysters, barbequed meat, oak leaves, coal, natural sediments and ordinary paving materials than in oil shale or its products or by-products. Although man is continually exposed to these items in a normal environment, these exposures have not been associated with human cancer.

The animal studies also concluded that normal exposures to oil-shale rock by workers and the local community during processing will not present unusual toxic or cancer-causing threats. The animals were exposed to massive amounts of small particles and dust from the native oil-shale rock and from the processed oil shale by skin contact, breathing and eating. They did not develop cancer, and no unusual or chronic toxic effects were found. The relative size of the doses given the animals exceeded any possible contact by humans. As stated earlier, animals painted with raw shale oil did develop skin cancer, but this problem is preventable by proper equipment design and good industrial hygiene practices.

Overall, the results of these analyses and tests demonstrate that modern industrial hygiene and safety practices in a commercial oil shale retorting facility will protect workers and others from cancer-causing materials and toxic risks similar to other safety practices in modern industry. The combined results of these studies will help form the basis for specific safety and health programs for all oil shale facilities.

1.2.14 Data Management

All air, water and microclimate data are currently in a computerized data base called RAMIS. Biological data are partly in manual data bases, as documented in data reports to the OSO and partly in RAMIS. Status is as indicated in Table 9-10 of Volume 1.

Data tapes for air quality and meteorology have been furnished to the OSO for data through April, 1980.

1.2.15 Reporting

Annual reports are submitted during the anniversary month of the Lease (April). Semiannual Data Reports are submitted to the OSO on January

15 and July 15. Air quality data volumes in these reports are also submitted to EPA, Region VIII, and the Air Quality Control Division of the Colorado Department of Health.

2.0 TRACT DEVELOPMENT SCHEDULE AND MAPS

2.1 Development Schedule

The proposed development schedule is presented as Table 3-1 and Figure 3-2 in Volume 1 of this report. A comparison of proposed vs. actual schedules for calendar years 1977 through 1980 is presented in Figure 3-3 of Volume 1.

2.2 Maps

Three fold-out charts (Exhibits A, B and C) depicting the monitoring site locations for development monitoring are included in the jacket inside the back cover of this volume. Exhibit A is a map of the Piceance Basin giving key features of the hydrologic monitoring program. Exhibit B is a list of stations of the hydrologic monitoring program illustrated in Exhibit A. Exhibit C is a map of the development monitoring activities at the site. Monitoring locations are shown as four-digit computer codes on the map; comparisons of computer codes and "conventional" site locations are included in Appendix Table A2.2-1.

Other useful maps in the jacket of Volume 1 include:

1:7200 Topographic Map of the Tract
1:7200 Aerial Mosaic (September 1980 overflight)
1:2400 Topographic maps of three selected areas of the Tract (further reduced in size)

Related maps are included in each chapter as appropriate.

3.0 INDICATOR VARIABLES

Indicator variables are those monitored, environmental parameters that can be expected to provide the earliest clues of potential change from the baseline environment. This section identifies the indicator variables selected for environmental disciplines of hydrology, air quality and meteorology, noise, and biology. Site locations are shown on the jacket map.

3.1 Role in Impact Assessment

These variables are: (1) most sensitive to change in quality; (2) indicators of natural or climatic change; and (3) subject to Federal and State standards because of concern for human health and public welfare.

Via early data reduction and analysis, changes or adverse time-trends in the observations can be flagged in timely fashion. Visibility is provided by maintaining current time-series plots of the key variables. Impact of development activity is also assessed through statistical comparison of data collected on both development and control sites. If trends and differences signal adverse environmental impact, additional and increased monitoring will be triggered. (Referred to as Systems Dependent Monitoring.)

3.2 Identification of Class I Indicator Variables

Indicator variables are that subset of the environmental parameters that best indicate the "state" of the ecosystem. However, the combinations of monitored indicator variables combined with the number of collection stations exceed 1000. Therefore, Class I Indicator Variables have been identified in order to further reduce the number of parameter and site combinations to a realistic quantity (147) for the purpose of close observation and more detailed analysis. Class I Indicator Variables are key environmental variables collected at representative stations on at least monthly frequency. Time series plots are maintained and updated semiannually for all Class I Indicator Variables.

This section identifies only the Class I Indicator Variables, however, all monitored variables are included in the data reports.

3.2.1 Tract Photography

Tract photography is carried out annually under both a surface and an aerial program. The aerial program this year consisted of historical and present use of Landsat digital data. No Class I Indicator Variables associated with tract photography are identified at present.

3.2.2 Hydrology and Water Quality

Class I Indicator Variables for hydrology are identified in Table 3.2.2-1. The number of collection sites has been screened to four USGS Gauging Stations, four springs and seeps, and four alluvial wells. Parameters are collected either daily or monthly as indicated by the codes in the table.

TABLE 3.2.2-1

HYDROLOGY CLASS 1 INDICATOR VARIABLES

	MAJOR U.S.G.S.				SPRINGS AND SEEPS				ALLUVIAL WELLS			
VARIABLE	WU07	WU61	WU58	WU22	WS01	WS03	WS06	WS07	WA03	WA05	WA06	WA08
1. Ammonia	M	M	M	M								
2. Boron	M	M	M	M								
3. Fluoride	M	M	M	M								
4. Total Dissolved Solids	M	M	M	M								
5. Arsenic	M	M	M	M								
6. Sediment	M	M	M	M								
7. Precipitation			M	M								
8. pH	D	D	D	D	M	M	M	M	M	M	M	M
9. Temperature	D	D	D	D	M	M	M	M	M	M	M	M
10. Flow	D	D	D	D								
11. Conductivity	D	D	D	D	M	M	M	M	M	M	M	M
12. Dissolved Oxygen	D	D	D	D	M	M	M	M				
13. Level									M	M	M	M

NOTES: Frequency of data sampling is coded: D for daily average of continuous sampling; M for monthly samples. Precipitation measurements are not taken at stations WU07 or WU61.

3.2.3 Air Quality and Meteorology

Class I Indicator Variables and stations for air quality and meteorology are identified in Table 3.2.3-1. Collection frequency for those parameters coded with D is continuous; hourly averages are reported in the data reports. Daily averages and peaks calculated from the hourly averages are used in the time-series plots for these variables. Daily totals are plotted for those parameters coded with a T.

3.2.4 Noise

Noise is measured at three stations in decibels. Class I Indicator Variables, shown in Table 3.2.4-1, are peak measurements of noise level for daytime (0700 through 1900 hours) and for nighttime (1900 through 0700 hours).

3.2.5 Biology

Much of the biological data collection and analysis is in a seasonal or annual time frequency. These data and analyses are important indicators of possible oil shale development environmental impact. However, under the definition of Class I Indicator Variables (those variables with at least a monthly collection frequency), a much smaller set of biological environmental parameters are identified. These parameters and their collection frequencies are shown in Table 3.2.5-1. The collection frequency of microclimate data is twice monthly and is indicated by 2M in this table. Monthly and weekly collection frequencies are shown in the table with M and W, respectively.

TABLE 3.2.3-1

AIR QUALITY AND METEOROLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS						
	AB20	AA23	AB23	AC20	AD42	AD56	AREA
1. SO_2	D		D				
2. H_2S	D		D				
3. O_3	D		D				
4. NO_x	D		D				
5. NO_2	D		D				
6. CO	D		D				
7. Particulates (every 3rd day)	T		T			T	
8. WS - 10m	D	D			D	D	
9. WD - 10m	D	D			D	D	
10. WS - 30m		D					
11. WD - 30m		D					
12. RH			D				
13. TEMP - 10m	D		D		D	D	
14. PRESS			D				
15. SOLAR			T				
16. ∇TEMP - (60m-10m)		D					
17. PRECIPITATION	T		T				
18. EVAPORATION			T				
19. INV HT				D			
20. VISUAL RANGE (every 6th day in Spring and Fall)							VR

NOTES: Frequency of sampling is continuous for all variables except visual range. Evaporation measurements are confined to the growing season. Daily averages with min and max hourly values are plotted for those variables coded with D. Daily totals are plotted for those coded with T.

TABLE 3.2.4-1

NOISE CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS	
	NA02 & NA09 (combined)	NB15
1. Daytime Noise (0700-1900)	P	P
2. Nighttime Noise (1900-0700)		P

NOTES: Discrete traffic noise measurements are recorded at Stations NA02 and NA09 one day each week. The peak db level (recorded here as P) for the two stations is plotted.

Continuous sampling of noise is conducted for 24-hours every sixth day at Station NB15. The peak db level for two 12-hour intervals is designated here as P.

TABLE 3.2.5-1

BIOLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	MICROCLIMATE STATIONS BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	U.S.G.S. WU07	WU61	PICEANCE CREEK ROAD	TRAFFIC CB	PCN	PCE
1. PRECIPITATION	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
2. SNOW DEPTH	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
3. TEMP MAX	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
4. TEMP MIN	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
5. PERIPHYTON BIOPRODUCTIVITY											M	M				
6. DEER ROAD COUNT													W			
7. DEER ROAD KILLS													W			
8. TRAFFIC COUNT														W	W	W

NOTES: Microclimate data are collected twice monthly (2M);
Periphyton bioproductivity collected monthly (M);
and Deer and Traffic are counted weekly (W).
CB - Traffic Count between Piceance Creek Road and C-b Tract.
PCN - Piceance Creek Road north of C-b turnoff.
PCE - Piceance Creek Road east of C-b turnoff.

4.0 TRACT PHOTOGRAPHY

4.1 Surface Program

4.1.1 Scope

Section 1 (C) of the Environmental Lease Stipulations requires that the Lessee conduct monitoring programs to measure perceptible changes from baseline conditions. Toward this end both a surface and an aerial photography program have existed since baseline. For the surface program, color photos were obtained annually at 35 photo points and color infrared photos were taken in the vicinity of the springs and seeps.

4.1.2 Objectives

The objectives of the surface program are to provide: 1) a visual record of changes from conditions existing prior to development operations; 2) visual evidence of successional changes in the ecosystem; 3) an historic account of surface development.

4.1.3 Experimental Design

Thirty-five points have been selected for development monitoring from which a 360° pan is photographed in color on a yearly basis (Figure 4.1.3-1). A 35mm camera with an f 1.8, 55mm lens is used. Once each year in June between 10:00 a.m. and 2:00 p.m. on cloudless days, a 360° photo pan is taken from each of the thirty-five photo map stations.

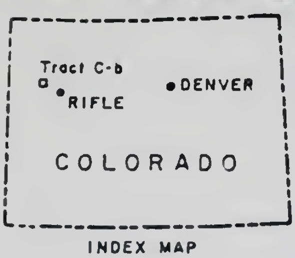
A color infrared pan is taken twice throughout the growing season around the nine spring-and-seep locations, to qualitatively record the vigor of growing vegetation at that time. These pans are contained in the semiannual data reports.

4.1.4 Archiving Methods

A complete set of the 35mm color slides for all photo points are numbered as to station, aspect, and date. This set is stored in plastic envelopes and bound in a three-ring binder, then filed in a unit designed to curtail dust and light as a part of the permanent record of the C.B. Shale Oil Project.

4.1.5 Results and Conclusions

As in the previous years the ground color slides have been archived as a photographic record of Tract changes. Color infrared photo pans of the areas around the springs and seeps have been taken twice during the growing season to record qualitative changes during the vegetative growth cycle.



INDEX MAP

SURFACE PHOTOGRAPHY NETWORK

FIGURE 4.1.3-1

4.2 Remote Sensing

4.2.1 Scope

Digital data from the multi-spectral scanner aboard the Landsat series of earth-orbiting satellites were used to assess the vegetation condition in the vicinity of the C-b Tract. The wide area coverage and resolution are adequate for general vegetation condition assessment.

The measure of vegetation condition is based on results obtained by Maxwell, et. al. (1980). The methods they employed were developed for short grass prairie and irrigated row crop vegetation; therefore, an extension of these methods to the pinyon-juniper forests and shrublands of the Piceance Basin has been derived.

4.2.2 Objectives

The objectives of this effort are:
1) to evaluate various filtering algorithms designed to reduce random variations in vegetation index values in the processed Landsat images; 2) to calibrate the normalized difference index for chained pinyon-juniper rangeland and hay meadows found within the Piceance Creek Basin; and; 3) to provide a measure of vegetation condition over a selected portion of the Piceance Creek Basin; and 4) to provide a measure of vegetation condition change over a growing season and over years.

During these analyses, and as an integral part of the effort undertaken, a major part of the image analysis software package called the Landsat Mapping System (LMS) was transferred to Occidental from Colorado State University Research Institute. This accomplishment, combined with satisfaction of the technical objectives noted above, has prepared Occidental to routinely employ Landsat to monitor changes in vegetation condition (green standing crop biomass).

4.2.3 Experimental Design

4.2.3.1 Selection of Critical Areas

The test area has been shifted east and south from previous studies in order to include a larger portion of the on-Tract area, the assumed area of drawdown, and the land application (sprinkler) system. Six areas were designated as areas of concern:
1. Riparian area below discharge point.
2. Riparian area above discharge point.
3. Chained pinyon-juniper area for maximum effects.
4. Sprinkler system area of influence for irrigation, initiated in June, 1980.
5. Control areas for dewatering effects and sprinkler system influence.
6. General condition of the disturbed area surrounding the Service, Production, and Ventilation/Escape shafts.

The location of the test area and the six areas of concern are shown in Figure 4.2.3-1.

FIGURE 4.2.3-1
LANDSAT TEST AREA AND SIX AREAS OF CONCERN

4.2.3.2 Selection of Dates

Eight image dates were selected for this analysis: June, 1977; August, 1977; June, 1979; August, 1979; June, 1980; July, 1980; August, 1980; and September, 1980.

The 1977 and 1979 image dates were selected for the initial study. Dates from 1980 were selected to correspond to the initial dates (i.e. months) and more frequently in order to establish a calibration curve for the chained pinyon-juniper woodlands.

Data for the August, 1977 Landsat computer compatible tape (CCT) from the EROS Data Center should be considered marginal from row 50 and beyond due to a format discrepancy which is not compatible with the current software. In addition, the image from June, 1979 has a cloud in the lower right-hand corner that eliminated this portion of the data from any comparative analysis.

4.2.3.3 Field Measurements

A field sampling program was initiated in May, 1980 and continued through September, 1980. The sampling dates were chosen to correspond with Landsat overpasses. Ten sample transects were established; five each in the Piceance Creek meadows and the upland ridges (chained pinyon-juniper areas). One square meter sampling quadrats were used on the ridges and 1000 cm^2 quadrats were employed in the meadows. A double sampling procedure was used to obtain biomass values for the quadrats that were randomly placed within the ten sample transects. Ocular estimates of biomass were made for each quadrat, and the green vegetation in every fifth quadrat was clipped and weighed. Approximately ten quadrat samples were taken for each transect.

4.2.3.4 Vegetation Index Calibration

The establishment of the relationship between biomass and Vegetation Index (VI) values required the registration of Landsat images with the region around the C-b site. The ROTATE program within the LMS package corrects for image distortion and scales the image for any specified delay device and map scale. The images for each of the overpass dates were rotated and scaled to overlay 1:24,000 maps of the region. In this way, the Landsat pixels located within the sampled meadow (M) and ridge (R) sites could be extracted from the Landsat CCTs and plotted vs. the measured biomass values for those locations. Because the relationship between vegetation index values and biomass is nonlinear and not well-defined, a graphical representation of that relationship is more useful than a linear regression equation (see Figure 4.2.5-3).

4.2.3.5 Filtering Algorithms

Two filtering algorithms were considered in this analysis: a moving average or low pass filter and a minimum variance filter. The moving average filter operates by means of a 3 x 3 pixel mask that is moved across the image data. For each 3 x 3 area, a weighted average is calculated

and this average value replaces the pixel value. The values chosen for weighting the averaging process are selected such that the contribution of a particular pixel is a function of the distance of that pixel from the center pixel (see Figure 4.2.3-2).

The minimum variance filter also employs a 3 x 3 mask. Within this mask, however, pixels are considered in groups of three as illustrated in Figure 4.2.3-3. The variance among pixels for each of these three pixel aggregations is computed. In this way a measure of the gradient across the mask is obtained. The group of 3 pixels with the lowest variance (region of least gradient) is selected for computing a nonweighted average to replace the value of the center pixel.

A study area exhibiting sharp boundaries and homogeneous fields was chosen to evaluate the two filtering algorithms. The filtering study area, 68 x 49 pixels or approximately 3665 acres, is located along Piceance Creek. The area is characterized by rugged topography with local relief of 600 to 800 feet and moderate-to-steep slopes in ravine areas. The meadows along the Piceance Creek are the most homogeneous since they are cultivated for hay and nearly level. The ridges are generally homogeneous but exhibit a considerable "salt and pepper" appearance due to vegetation and topographic variations. The Landsat image of June 30, 1979 was selected for analysis. This image showed no evidence of striping or variations from line to line caused by incorrect detector calibration.

4.2.4 Method of Analysis

This technique utilizes the Landsat Earth resources satellite in a sun-synchronous orbit at 918 km. It passes over the area at the same local time (approximately 9:30 a.m.) each day, which is significant since any changes in shadowing would influence reflectance. Land coverage is approximately 110 x 110 square miles. The on-board sensor measures spectral reflectance in four discrete bands:

Band	Wave Length (um)	
4	0.5 to 0.6	Green
5	0.6 to 0.7	Red
6	0.7 to 0.8	Photo IR
7	0.8 to 1.1	Photo IR

The paragraphs to follow discuss the derivation of both change detection techniques and vegetation indices from information in these bands.

4.2.4.1 CCT Processing and Display Procedures

Software exists for extracting data for the test area from the Landsat Computer Compatible Tapes (CCT's), which is the first step in image processing. The next step in processing is to transform the data via systematic geometric corrections for Earth rotation and scanner mirror velocity, then to rotate the image to true north and scale it to 1:24,000 to precisely

0.18	0.30	0.18
0.30	1.00	0.30
0.18	0.30	0.18

FIGURE 4.2.3-2
MASK OF FILTER WEIGHTS USED TO EFFECT THE MOVING AVERAGE FILTERING ALGORITHM.

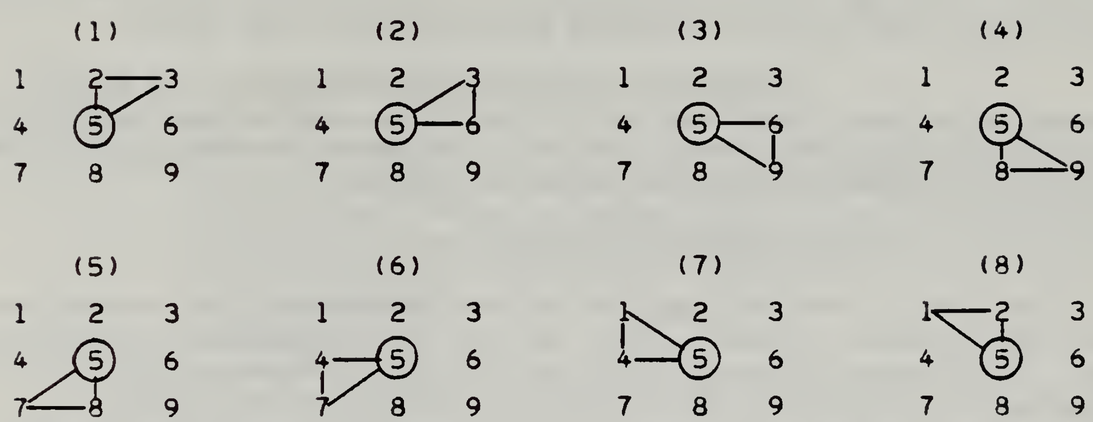


FIGURE 4.2.3-3

GROUPS OF THREE PIXELS WITHIN THE 3 X 3 FILTER MASK WHICH ARE USED FOR THE VARIANCE FILTER.

match the scale of USGS topographic maps. Geometric accuracy is expected to be plus or minus one resolution unit (pixel).

Once geometrically controlled, filtering was then performed on each data set for each channel, and the vegetation index for each data set was computed and added to that data set as a fifth channel of information. The data sets were then merged for comparison and differencing of the vegetation index was performed. A histogram of difference values was generated and used to select a threshold for mapping intensity of change. These intensity-of-change values in both positive and negative directions were displayed via line printer output as gray-scale maps. The Landsat data are similarly presented.

4.2.4.2 Change Detection

Several methods have been used to extract change detection information from digital data. These include: (1) an image-ratio technique whereby Landsat data for a designated test area are acquired for two different dates, (2) a post-classification comparison of land-cover classes between dates, (3) the use of data reduction techniques to emphasize particular data characteristics for the identification of change, and (4) image-differencing employing the subtraction of one data value from another.

Several points should be noted in change detection. Data transformations are useful to enhance quality of the data that are of interest. This can reduce noise in the data and lead to economy in data processing. The comparison of individual classification results to determine areas of change is useful since data-specific noise, such as unique atmospheric effects, will have less effect on the results. A variety of change detection techniques exist that can be tailored to meet particular user needs.

Changes in vegetation condition were the primary measurement objectives; therefore, calculating differences between vegetation indices was the analysis method selected. A description of vegetation indices and their use to quantify vegetation condition follows.

4.2.4.3 Vegetation Indices

Two important factors determining leaf reflectance are the light absorbing pigments within the leaf and the physical structure of the leaf. The pigments (chlorophylls, xanthophylls, carotenoids, and anthocyanins) are responsible for absorption of energy in the visible wavelengths, but they do not interact with infrared (IR) energy (see Figure 4.2.4-1). The structure of the leaf is important to both visible absorptance and IR reflectance. Leaf structure increases the effective path length within the leaf for the visible and IR wavelengths. This increases the opportunity for the interception of radiation by the pigments and results in the upward scattering of 40 to 60 percent of the near IR energy intercepted by the leaf (Maxwell et.al. 1980).

The measurement of biomass (a term used to describe the quantity and vigor of green vegetation covering the surface which is assumed

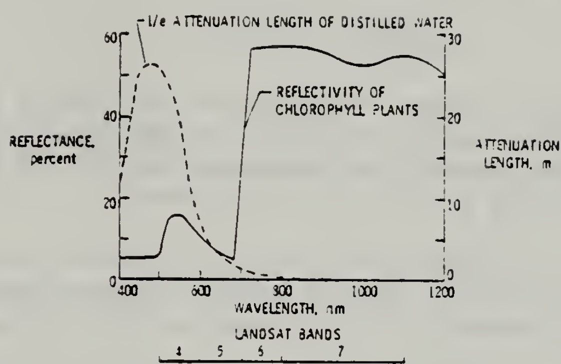


FIGURE 4.2.4-1

Landsat Reflectance vs. Wavelength

This illustration represents the wavelengths monitored by the four Landsat sensors along with the reflectance characteristics of plants and attenuation of radiation by water. Note the high absorption of band 5 radiation by chlorophyll and the enhanced band 6 and 7 reflectance due to leaf structure. High attenuation is noted for band 7 due to water absorption.

to be directly related to vegetation condition) using vegetation indices has been the subject of much research during the past decade. This previous research, in particular that of Maxwell et. al. (1980), prompted the initial evaluation of Landsat vegetation indices for monitoring seasonal and annual changes in biomass in the Piceance Creek Basin.

The results of the initial study in 1979 verified the feasibility of using Landsat vegetation indices to monitor biomass changes in the chained pinyon-juniper rangelands and in the hay meadows along the Piceance Creek. The normalized differences (ND) index derived from Landsat bands 7 and 5 was shown to be the most useful for this application. This index is computed according to the equation:

$$ND = \left(\frac{b-a}{b+a} + 1\right) 125 \qquad \text{Equation (1)}$$

where a = the digital number recorded for MSS band 5 (0.6 to 0.7 um),
b = the digital number recorded for MSS band 7 (0.8 to 1.1 um),
and the other numbers are constants which keep ND values within a 0 to 225 range for normal conditions.

Although the spatial resolution of Landsat is marginal for monitoring biomass changes along Piceance Creek, it is adequate for the upland range areas characteristic of most of the Piceance Creek Basin.

It should be emphasized that these indices respond only to green vegetation and they must be used at the appropriate time of the year. Senescent (brown) vegetation is spectrally similar to bare ground and cannot be distinguished by Landsat imagery.

4.2.5 Discussion and Results

4.2.5.1 Field Measurement Results

The field measurement program conducted by C.B. was carried out successfully and produced a reliable record of biomass variations during the growing season (May to September). The field data were used to calibrate the ND vegetation index, producing the results described here.

Figure 4.2.5-1 shows a plot of the ocular estimates for the meadow sites on August 8, 1980. The scatter around the regression equation derived from the clipped data is minimal and verifies the quality of the data obtained from the field measurements. The data also appear well-behaved in Figure 4.2.5-2 which is representative of all meadow and ridge sites, and show the seasonal variation of green standing crop biomass. The meadows were harvested between the late July and early September sample dates. Also, the biomass on the ridge sites is shown to be much lower and gradually decreases during the growing season. Although somewhat limited in the range of biomass values represented, the data were useful for calibrating the normalized difference vegetation index.

4.2.5.2 Vegetation Index Calibration Results

Landsat computer compatible tapes (CCTs) were obtained

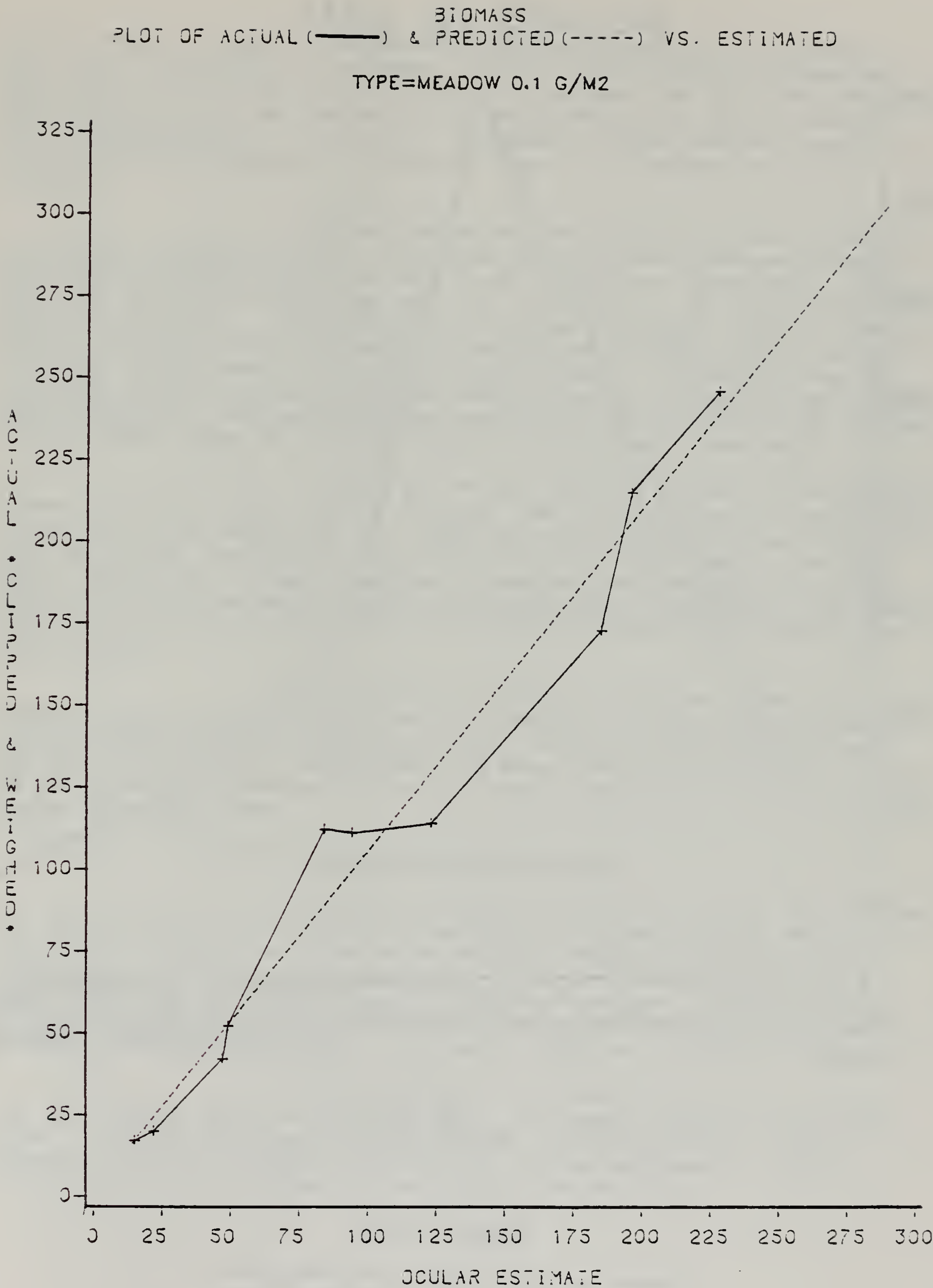


FIGURE 4.2.5-1

A plot of ocular estimates of biomass vs. clipped and weighed actual values. The dashed line is the regression equation used to correct the estimates for samples not clipped.

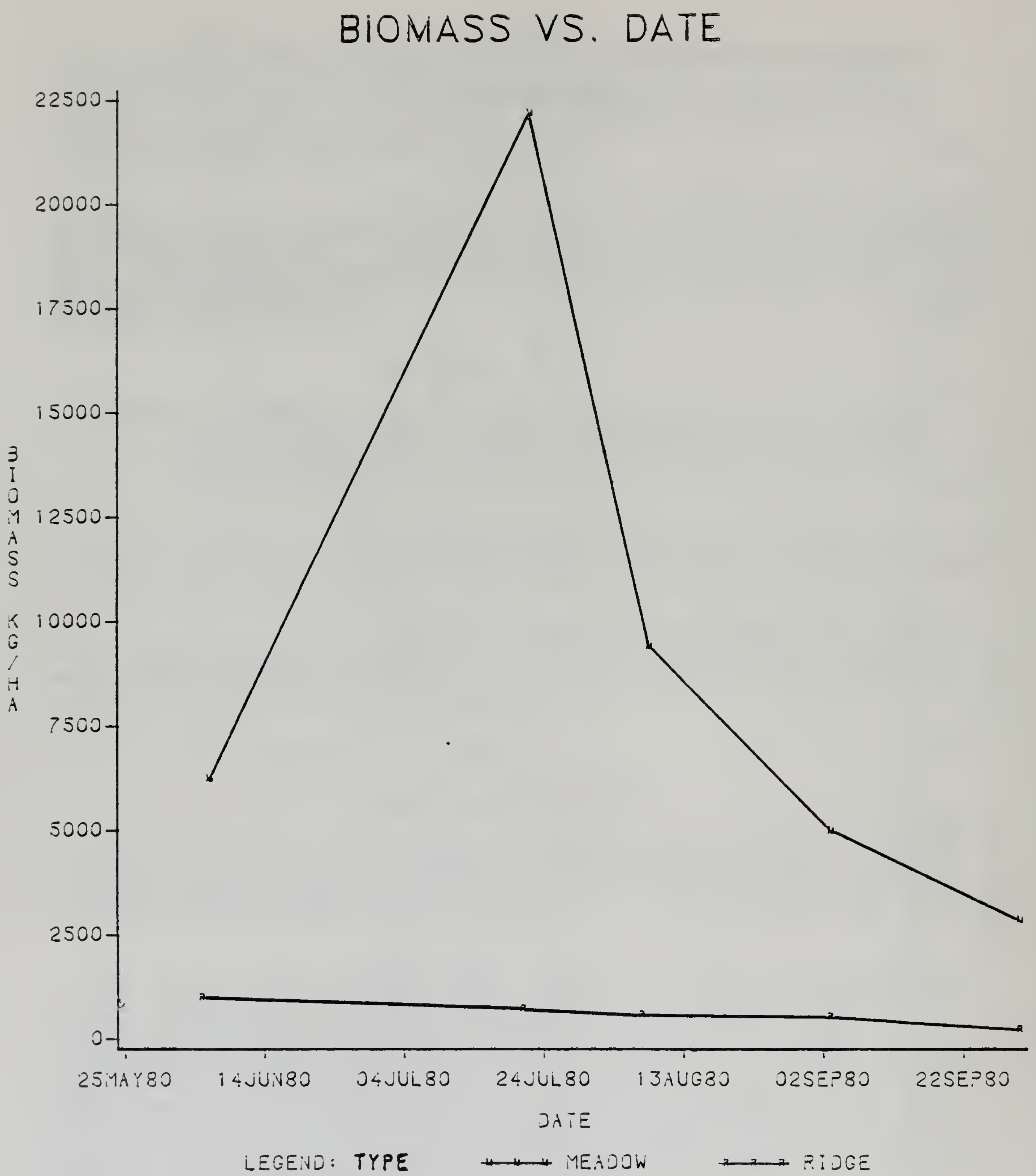


FIGURE 4.2.5-2

Biomass variations during the growing season for meadow and ridge (chained Pinyon-Juniper) test sites. Sharp decline of meadow is a result of harvesting.

for one overpass in each of the months of June, July, August, and September, 1980. With the exception of September, the field measurements of biomass were made within a day of the Landsat overpass. In September the field measurements were conducted on the 3rd and 30th of the month whereas the Landsat overpass occurred on September 21. Due to this difference in dates and the related low solar altitude in September, the September data were eliminated from the analyses.

Data were extracted from the CCTs for each of the 10 field sites for each image date. The normalized difference index was computed according to equation (1) and the results were plotted on Figure 4.2.5-3. The mean index value from Landsat for each site is plotted vs. the average measured biomass at that site. The curves derived by Maxwell, et. al. (1980) for rangeland and irrigated crops where shown in the 1979 Annual Report. The lower part of Maxwell's curves were fit to grass rangeland data (0 - 5000 kg/ha) and the upper part of these curves intercepted data obtained for irrigated crops (10,000 to 60,000 kg/ha). Some deviation from these curves was expected for the chained pinyon-juniper ridges and irrigated meadows of the Piceance Creek Basin.

In general, the data show the expected relationship between index and biomass values. The data from the ridge sites fall very close to the curves from Maxwell, et. al. (1980) but are significantly lower than the mean (solid line) from Maxwell presented in the 1979 Annual Report. The high biomass meadow data obviously represent a departure from the upper part of the curve, but this is not surprising since the vegetation index-biomass relationship for row crops would be expected to be different from the relationship for grassy meadows.

Unfortunately, there is a large gap in the data between biomass values of 1,000 kg/ha and 5,000 kg/ha. Furthermore, the meadow and ridge vegetation is quite different and a smooth connection between these data sets may not exist. Nevertheless, the heavy line in Figure 4.2.5-3 is useful for estimating biomass values in the Piceance Creek Basin. Future data will further define this curve.

4.2.5.3 Filtering Algorithm Results

The filtering analysis has clearly shown the different characteristics of the moving average (MA) and minimum variance (MV) algorithms. The decision to use one or the other depends on the particular characteristics of the scene being considered and the specific application at hand. One to six iterations of the MV filter were analyzed. Optimum results for this data set appeared to be contained from six iterations and only these MV results will be shown.

Figure A4.2.5-1 is a graymap of MSS Band 7 of the area used to test the filtering algorithms. The transect used to observe the effect of filtering on boundaries is outlined. Figure A4.2.5-2 is a Band 7 graymap of the same area after the MA filter had been employed and Figure A4.3.5-3 shows the area after six iterations of the MV filter.

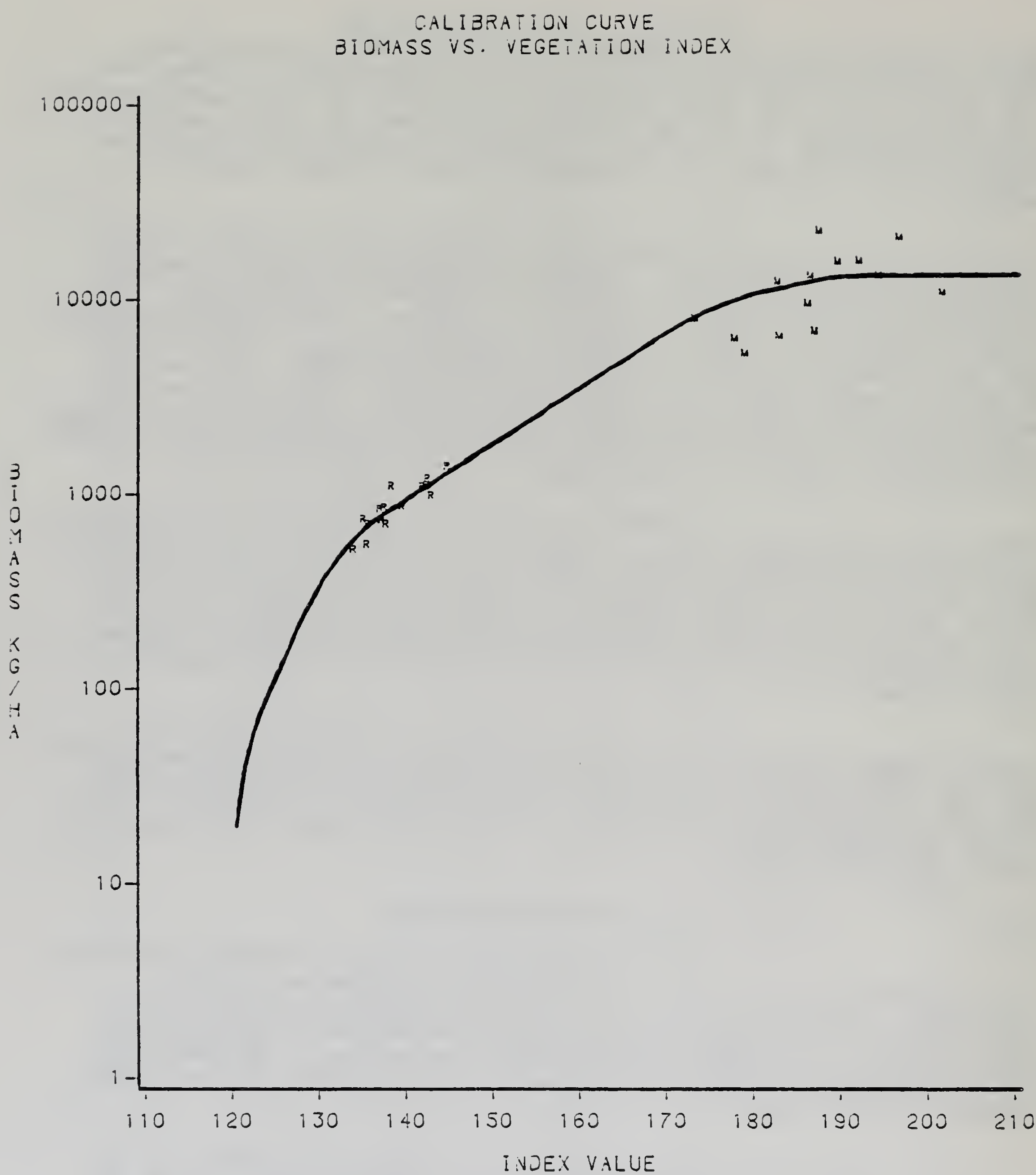

CALIBRATION CURVE
BIOMASS VS. VEGETATION INDEX
100000
10000
1000
100
10
1
BIOMASS KG/HA
110
120
130
140
150
160
170
180
190
200
210
INDEX VALUE

FIGURE 4.2.5-3

The differences in these Band 7 graymaps show the effects of the filtering algorithms. Both Figures A4.2.5-2 and A4.2.5-3 show a reduction in "salt and pepper" noise. Figure A4.2.5-3 has retained more of the structure of the scene, however, and has actually sharpened the boundaries between some portions of the scene. The MA filter has broadened narrow features and boundaries. This is more evident in Figure A4.2.5-4 where Band 7 values across the transect are displayed for unfiltered, MA and MV filtered data. Obviously the MA filter (Figure A4.2.5-4) has accomplished the most smoothing, but to the detriment of narrow features. Even the broad Piceance Creek meadow has been severely distorted. Figure A4.2.5-5 shows transects for Band 5 with similar results.

As long as "noise" variations are primarily represented by pixel to pixel variations, the MV filter is definitely superior. If noise were occurring in groups of 3 or more pixels, however, this filter would not effect much smoothing, but in fact, might tend to further enhance such large noise features. The use of filters should always be designed for each scene, remote sensing system, and application. Use of filters should be based on the system modulation transfer function, the spatial frequency content of the scene, and the desired objectives.

4.2.5.4 Vegetation Index and Change Detection Results

The normalized difference value of the vegetation index used in this analysis can be represented in simple form as:

$$ND = \frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}}$$

Band 7 characterizes enhanced infrared reflectance where as Band 5 illustrates the effects of chlorophyll absorption.

A derivation in the appendix of last year's report was presented to stress that the normalizing effect of the vegetation index can be expected to improve comparisons between data by the reduction of atmospheric, topographic, and soil background variations.

Figures 4.2.5-4 and A4.2.5-6 to A4.2.5-12 are graymaps of the vegetation index for the flight image dates. Subareas one and two are the portions of the test area indicating regions of substantial green biomass. Subareas three through six show no obvious topographic influence. Comparison of these vegetation graymaps with Figure 4.2.5-5 (a black and white aerial photograph of the region) indicates that any topographic relief in the vegetation index map is generally a result of low vegetation associated with the topography (note the northern bank of Piceance Creek).

By comparing the June 1977, June 1979 and June 1980 image dates, one can note a general increase in biomass from 1977 - 1980. This is to be expected since 1977 was a drought year, 1979 was closer to normal and 1980 is considered a wet year. Later in the growing season of each year, comparisons show an increase in biomass from August 1977 to August 1979 and August 1980, with a decrease shown from August 1979 to August 1980. This

THE CHARACTER SET USED FOR DISPLAY IS GREEN BIOMASS (KG/HA)

FROM	0.00	TO	90.00	DISPLAYED	W	0 (WATER)
FROM	91.00	TO	121.00	DISPLAYED		0 (BARE SOIL)
FROM	122.00	TO	125.00	DISPLAYED	.	0 - 175
FROM	126.00	TO	130.00	DISPLAYED	+	175 -475
FROM	131.00	TO	137.00	DISPLAYED	*	475 - 800
FROM	138.00	TO	147.00	DISPLAYED	=	800 - 1525
FROM	148.00	TO	157.00	DISPLAYED	■	1525 - 2950
FROM	158.00	TO	169.00	DISPLAYED	x	2950 - 6300
FROM	170.00	TO	180.00	DISPLAYED	O	6300 - 10900
FROM	181.00	TO	191.00	DISPLAYED	θ	10900 - 13000
FROM	192.00	TO	202.00	DISPLAYED	⊖	> 13000
FROM	203.00	TO	213.00	DISPLAYED	●	> 13000
FROM	214.00	TO	256.00	DISPLAYED	▣	> 13000

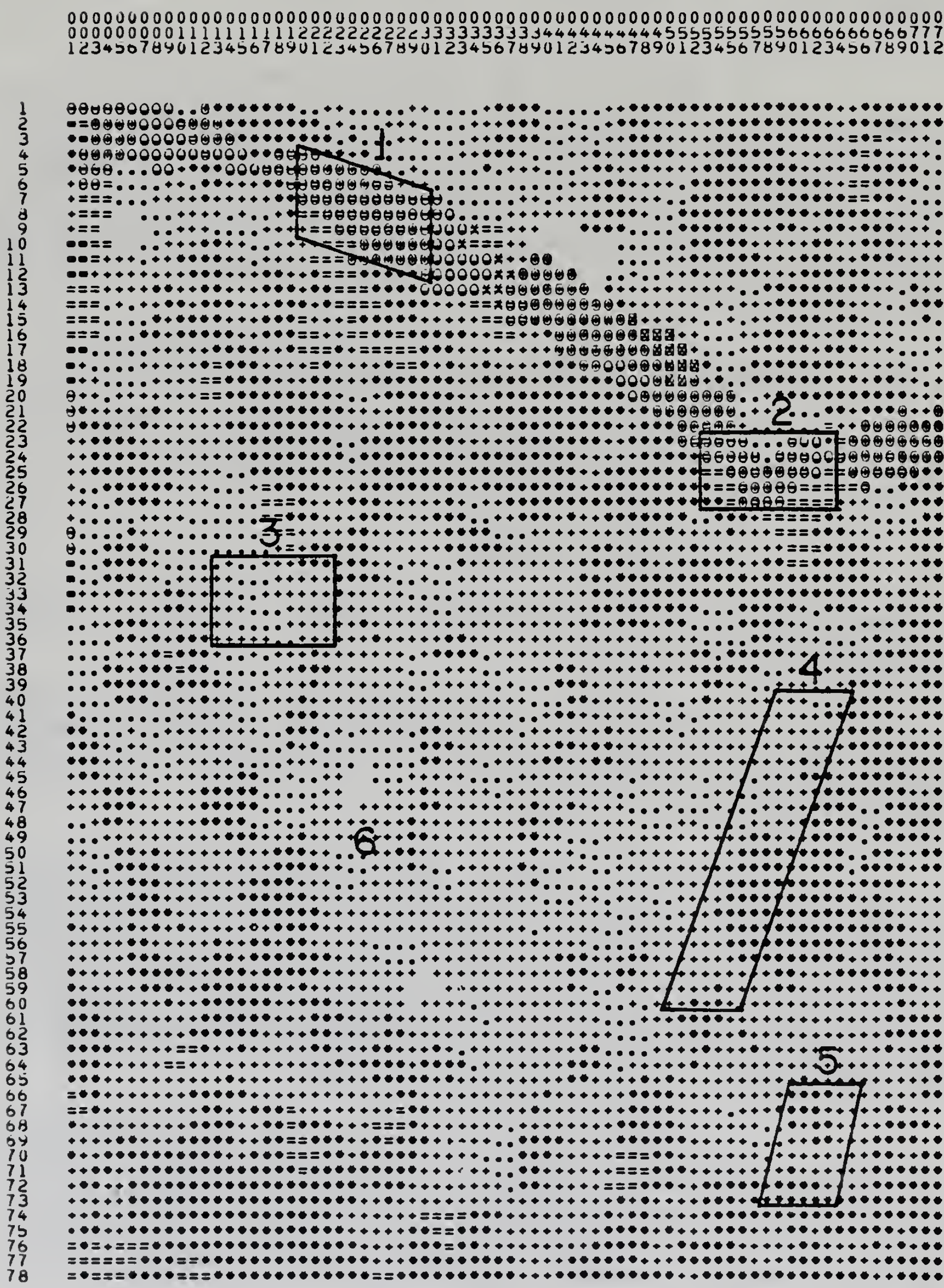


FIGURE 4.2.5-4

Graymap of the Vegetation Index (Normalized Difference). June, 1977 Image Date.

FIGURE 4.2.5-5

Aerial Photograph of Piceance Creek Test Area
September 5, 1979 Image Date.

decrease could be due to length of the growing season, degree days during the growing season, or the total precipitation during the summer months. Results are supported by the maps of change detection shown in Figures A4.2.5-13 to A4.2.5-18.

Figures A4.2.5-19 to A5.2.5-23 show the seasonal change detection graymaps produced by the comparisons of June vs. August 1977, June vs. August 1979 and June vs. July-September 1980. The uplands areas are characterized by a negative change except for 1979 which again indicates that August of 1979 was a high biomass month. The riparian areas are characterized by fluctuating changes between positive and negative changes. These fluctuations could be due to harvest of the hay fields.

Table 4.2.5-1 is a summary of both between-years and seasonal change for each study site. The information included in this table is:

1. Mean index value for each site.
2. Percent change in the means using the image date in the first column as a reference.
3. Mean index value for each site after differencing.
4. Type of change associated with the differenced index value.

Note: Item 4 describes any significant change whereas item 2 describes any change in the means.

The significance for each site shown in the table is as follows:
Site

1 - Located in the riparian area along Piceance Creek below the Pond A/B discharge point.

2 - Located in the riparian area along Piceance Creek above the Pond A/B discharge point.

- Changes in sites 1 and 2 could be and most likely are due to harvest of these grassland areas for hay.

3 - Located off-tract in the chained pinyon-juniper area, suspected to be an area to register the maximum dewatering effects.

4 - Located on-tract in the sprinkler irrigation system area to show the influence of the sprinkler system. Operation of the irrigation system started in June, 1980 therefore making data for 1977 and 1979 not applicable for this purpose.

5 - Located on tract as a control area for sites 3 and 4.

6 - This is a large site, approximately 16 x 27 pixels, surrounding and including the disturbed area of the development site. The primary purpose is to monitor the changes due to construction and development in this area.

4.2.6 Conclusions

The results of this analysis have shown that Landsat derived vegetation indices can be used to measure green standing crop biomass in the

TABLE 4.2.5-1

Summary of Change
June 1977 - September 1980

SITE	JUN 1977		AUG 1977		JUN 1979		JUN 1980	
1	186	***	166	-11%	190	+2%	177	-5%
	***	***	80	--	104	=	91	=
2	172	***	159	-8%	179	+4%	176	+2%
	***	***	87	--	108	+	105	=
3	127	***	122	-4%	132	+4%	142	+12%
	***	***	95	=	106	+	115	++
4	129	***	127	-2%	132	+2%	140	+9%
	***	***	97	=	102	=	110	+
5	130	***	127	-2%	CLOUD		144	+11%
	***	***	97	=			114	++
6	128	***	123	-4%	126	-2%	135	+5%
	***	***	96	=	99	=	107	+

SITE	AUG 1977		AUG 1979		AUG 1980	
1	166	***	187	+13%	160	-4%
	***	***	121	+++	94	-
2	159	***	189	+19%	162	+2%
	***	***	130	+++	103	=
3	122	***	136	+11%	133	+9%
	***	***	114	++	111	++
4	127	***	137	+8%	135	+6%
	***	***	111	++	108	+
5	127	***	141	+11%	137	+8%
	***	***	114	++	110	+
6	123	***	129	+5%	129	+5%
	***	***	106	+	106	+

SITE	JUN 1979		AUG 1979		JUN 1980	
1	190	***	187	-2%	177	-7%
	***	***	97	=	87	--
2	179	***	189	+6%	176	-2%
	***	***	110	+	97	=
3	132	***	136	+3%	142	+8%
	***	***	103	=	109	+
4	132	***	137	+4%	140	+6%
	***	***	106	+	108	+
5	CLOUD		CLOUD		CLOUD	
6	126	***	129	+2%	135	+7%
	***	***	103	=	108	+

SITE	AUG 1979		AUG 1980	
1	187	***	160	-14%
	***	***	73	---
2	189	***	162	-14%
	***	***	73	---
3	136	***	133	-2%
	***	***	97	=
4	137	***	135	-1%
	***	***	98	=
5	141	***	137	-3%
	***	***	96	=
6	129	***	129	0
	***	***	100	=

SITE	JUN 1980		JUL 1980		AUG 1980		SEP 1980	
1	177	***	189	+7%	160	+10%	190	+7%
	***	***	112	++	83	--	113	++
2	176	***	181	+3%	162	-8%	176	0%
	***	***	105	=	85	--	100	=
3	142	***	136	-4%	133	-6%	134	-6%
	***	***	94	-	91	-	93	-
4	140	***	136	-3%	135	-4%	139	-1%
	***	***	96	=	95	=	99	=
5	144	***	140	-3%	135	-5%	136	-6%
	***	***	96	=	93	-	92	-
6	135	***	131	-3%	129	-4%	131	-3%
	***	***	96	=	95	=	97	=

LEGEND

*** - NO VALUES (REFERENCE DATE)

MEAN INDEX VALUE	% CHANGE OF MEAN
MEAN INDEX VALUE AFTER DIFFERENCING	TYPE OF CHANGE

TYPE OF CHANGE:
--- NEGATIVE (STRONG)
-- NEGATIVE (MILD)
- NEGATIVE
= NO CHANGE
+ POSITIVE
++ POSITIVE (MILD)
+++ POSITIVE (STRONG)

Piceance Creek Basin. Figure 4.2.6-1 shows the results of generating a map by assigning letters to the index values from the calibration curve for meadows (M) and ridges (R). The relationships between ND index value and biomass is similar to that found by Maxwell, et. al. (1980) for grass rangeland and irrigated crops.

FIGURE 4.2.6-1

Graymap Illustrating Calibration Curve Ranges

R = Ridges M = Meadows • = disturbed areas

5.0 HYDROLOGY AND WATER QUALITY

5.1 Introduction and Scope

A development monitoring program has been implemented to provide water quantity and quality data to determine if changes in flows or parameters exist, and if changes are detected, to determine whether the changes are natural or caused by development of the C-b Tract. Streams, springs, seeps, and wells in the the alluvium, upper and lower aquifers have been monitored since baseline. The program was expanded in 1979 to accommodate monitoring required by the Water Augmentation Plan and Court Decree (W3492) which includes monitoring of water pumped from shafts and the mine as it is developed, and additional monitoring of springs, wells, and precipitation stations. The generalized and simplified two-layer aquifer system concept guided the measurements of flows, levels, and water quality parameters. Figure 5.1-1 shows the generalized concept along with the more detailed set of aquifer units and the interval planned for retorting at Tract C-b.

This chapter presents the hydrologic analyses performed on data collected, with emphasis on data collected since October 1979. Quality assurance procedures have been previously discussed in the Development Monitoring Reports. Discussion is separated into two parts: levels and flows, and water quality.

In the baseline program all parameters measured were selected without previous knowledge of their importance. For example, water quality monitoring was instituted on ephemeral streams without knowledge of the flows. In addition, the baseline program revealed certain deficiencies in earlier concepts of the tract hydrology. The baseline program confirmed the complexity in hydrology and geology that was previously suspected. The earlier generalized description of two aquifers separated by the Mahogany zone is now outdated as supporting data show. A simplification of the more complex system is shown in Figure 5.1-1, including strata that have been tenatively considered, at least locally, to be aquitards. For purpose of identification, the new subdivisions are:

1) UPC_1 - Upper Parachute Creek #1: Approximate limits extend from the Uinta Formation to the top of the 4 Senators Zone.
2) UPC_2 - Upper Parachute Creek #2: Extends from the base of the 4 Senators Zone to the base of the A-Groove.
3) LPC_3 - Lower Parachute Creek #3: Extends from 30 feet below the base of the A-Groove to the top of the R-5 Zone.
4) LPC_4 - Lower Parachute Creek #4: Extends from the middle of the R-5 Zone to the base of the L-4 Zone.

The interval encompassed by the UPC_2 and LPC_3 subdivisions of the aquifer system conforms to the zone presently planned for retorting. This one will be dewatered during mining operations. Several bedrock wells were recompleted according to the more complex aquifer systems. Under the present development plans for C.B., the hydrologic monitoring program was revised to cover the changing phases of development. The first phase covered the period from the completion of the interim monitoring period to the completion of shafts. The second phase covers the period of lateral drifting and mine dewatering to retort construction. The third phase will cover the period of retort ignition and commercial mine construction and operation.

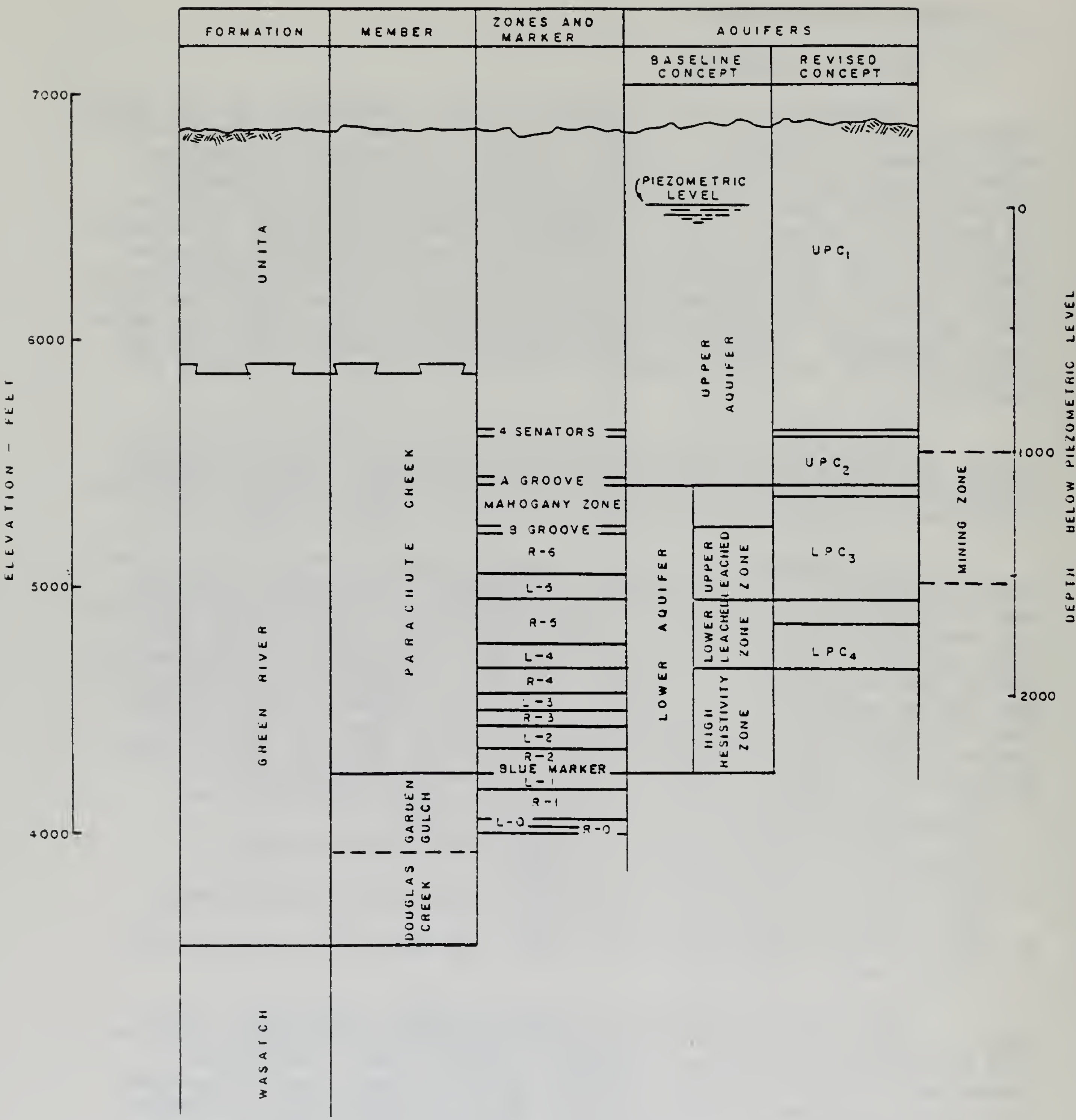


FIGURE 5.1-1

C-b Tract

STRATIGRAPHIC COLUMN AND AQUIFER CONCEPT

5.2 Levels and Flows

5.2.1. Streams

5.2.1.1 Scope

Thirteen stations on or near C-b Tract are operated and maintained by the U.S.G.S. Water Resources Division. Nine of the 13 stations are located on ephemeral streams, and the other four are considered major stations on perennial streams, and record stream flow continuously.

5.2.1.2 Objectives

The surface stream monitoring program has been implemented to determine if significant changes exist in levels and flows, and if changes are identified, to determine whether these changes are attributable to C-b Tract development.

5.2.1.3 Experimental Design

The monitoring network is conceptually the same as that used during the baseline period. Figure 5.2.1-1 is a map of the Tract showing the locations of nearby surface water monitoring stations included in the environmental monitoring program. Remote stations are shown in Figure 2.2-1 (map pocket). The monitoring program uses the stations included in the baseline program and one new station on Piceance Creek (Table 5.2.1-1).

Each of the stations listed in Table 5.2.1-1 were operated according to the sampling schedule shown on Figure 5.2.1-2. Since some stations are located on ephemeral stream courses, only intermittent flows were recorded.

5.2.1.4 Methods of Analysis

Analyses were performed by inspection of the hydrographs of daily mean flow, by comparison of total and mean annual streamflow data, by analysis of ratios of flows from different stations, and by analyzing the trends over time using the Box-Jenkins statistical technique. The Box-Jenkins technique is briefly described in the Appendix as A5.2.1.4.

5.2.1.5 Discussion and Results

Hydrographs of daily mean flow for stations WU07, WU61, and WU00 are shown in Figure 5.2.1-3 (period October 1973 through September 1977) and Figure 5.2.1-4 (period October 1977 through September 1980).

The hydrographs show the seasonal influences of runoff, evapotranspiration, and irrigation diversions. About 65 percent of the irrigation diversions occur in the late spring and early summer (April to July). Some 30 percent of the diversions occur in late summer and early fall (August to October). These diversions are reflected in the hydrographs, although those years where the spring is unusually wet will deviate from the pattern, e.g. 1979.

U.S.G.S. STREAM GAUGING STATION MONITORING NETWORK

FIGURE 5.2.1-1

TABLE 5.2.1-1
STATIONS CONSTITUTING THE SURFACE WATER MONITORING PROGRAM

Computer Code	USGS Number	Station Location	Comments
WU07	09306007	Piceance Creek below Rio Blanco, upstream from C-b Tract	To operate during the life of the Project. Baseline flow since April 1974, a major station. Continuous flow measurements.
WU61	09306061	Piceance Creek at Hunter Creek, downstream from C-b Tract	To operate during the life of the Project. Baseline flow since April 1974, a major station. Continuous flow measurements.
WU22	09306022	Stewart Gulch	Consider reduction if data are stable after a period of commercial operations. A major station. Baseline flow data since October 1974.
WU58	09306058	Willow Creek	Consider reduction if data are stable after a period of commercial operations. A major station. Baseline flow data since October 1974.
WU00	09306200	Piceance Creek near Ryan Gulch	One of the major monitoring stations on Piceance Creek. Baseline flow data since October 1964.
WU42	09306042	In "No Name Gulch" west of Cottonwood Gulch on C-b Tract	Used to monitor construction activities and mine area development. Ephemeral station. Baseline flow data since April 1974.
WU36	09306036	At mouth of Sorghum Gulch	To operate during the life of the Project. To monitor runoff from construction activities. Baseline flow since April 1974. Ephemeral station.
WU33	09306033	In Sorghum Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral station.
WU39	09306039	At mouth of Cottonwood Gulch	To operate during the life of the Project. To monitor stream runoff from surface facilities, ore storage piles, roads and construction areas. Ephemeral station. Baseline data since April 1974.
WU52	09306052	At mouth of Scandard Gulch	To operate during the life of the Project. Baseline data since October 1974. Ephemeral station.
WU50	09306050	In Scandard Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral station near southern boundary of C-b.
WU28	09306028	At mouth of West Fork of Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since April 1974.
WU25	09306025	In West Fork Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since April 1974. Ephemeral station.
WU15	09306015	In Middle Fork Stewart Gulch	To operate during Development Phase, to be reevaluated at a later date. Baseline data since October 1974. Ephemeral Station.
WU33	09306033	In Sorghum Gulch, upstream	To operate during Development Phase, to be reevaluated at a later date. To monitor runoff from construction activities. Baseline data since October 1974. Ephemeral station.
WU45	09306045	Piceance Creek 50 meters downstream from No Name Gulch and Piceance Creek confluence	New station constructed to monitor discharges from C-b Tract through No Name Gulch.
WU48	09304800	White River below Meeker	New station required by Water Augmentation Plan.
WU55	09306255	Yellow Creek near White River	New station required by Water Augmentation Plan.
WU62	09306222	Piceance Creek at White River	New station required by Water Augmentation Plan.

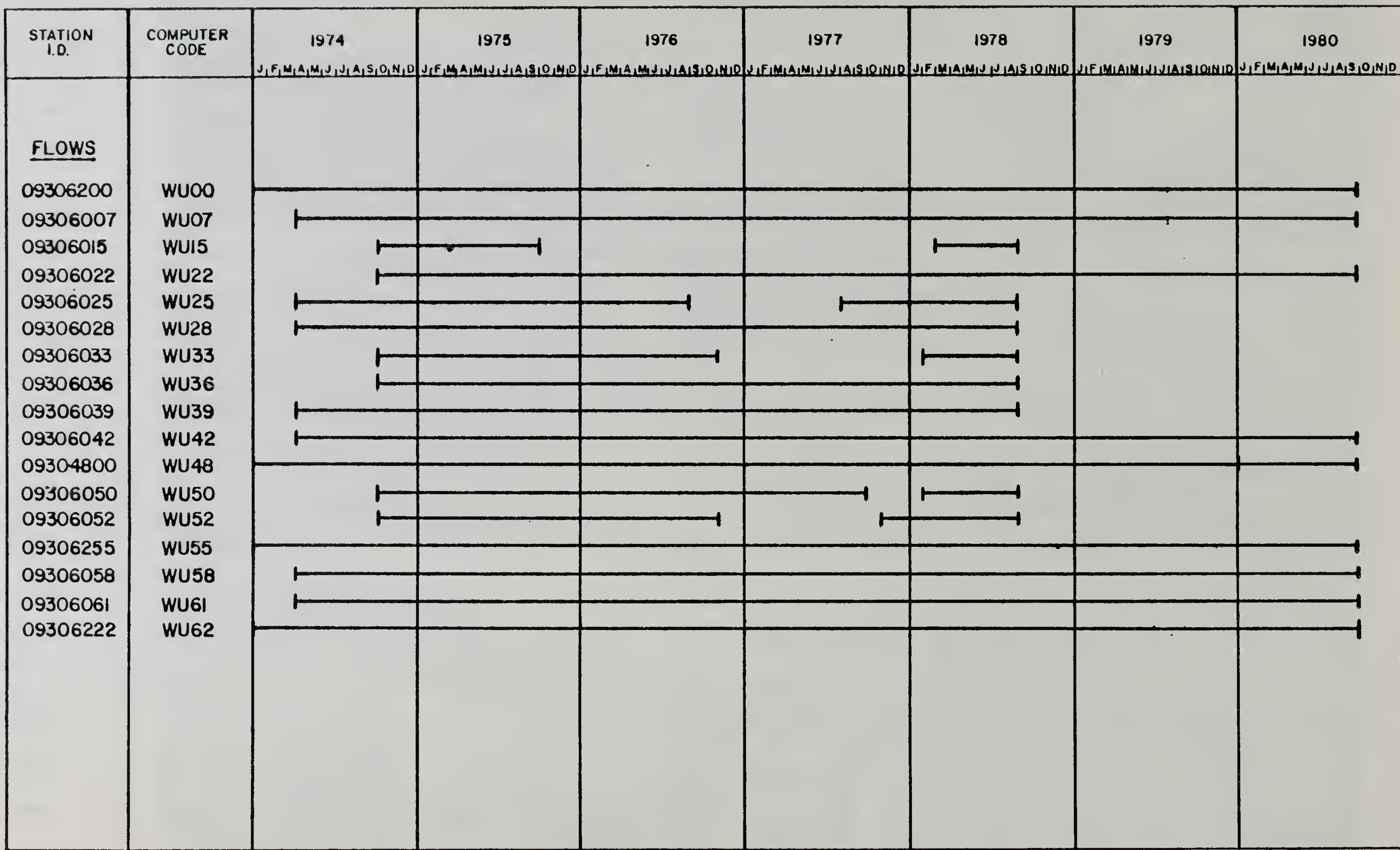
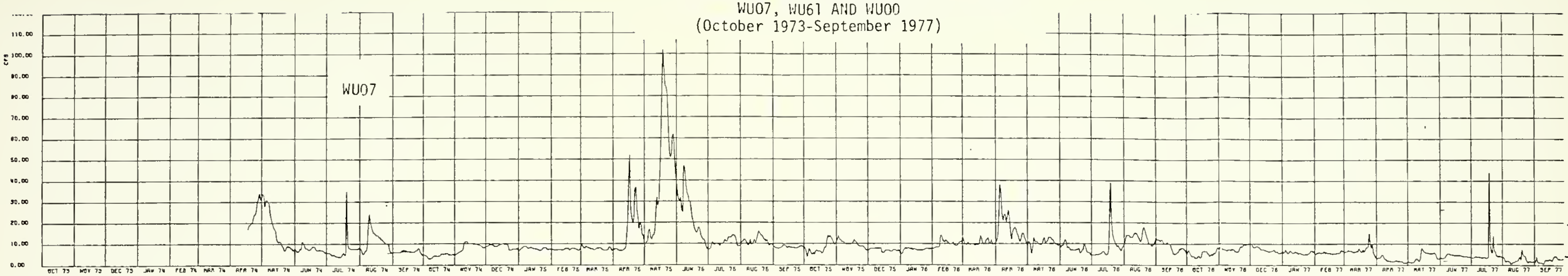


FIGURE 5.2.1-2
U.S.G.S. STREAM GAUGING STATIONS
SAMPLING TIME INTERVALS
FOR FLOWS

Figure 5.2.1-3
HYDROGRAPHS OF DAILY MEAN FLOW FOR STATIONS
WU07, WU61 AND WU00
(October 1973-September 1977)



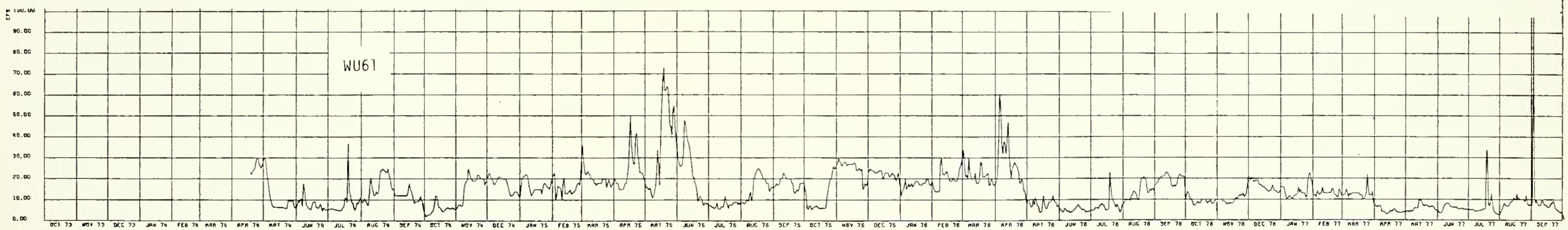
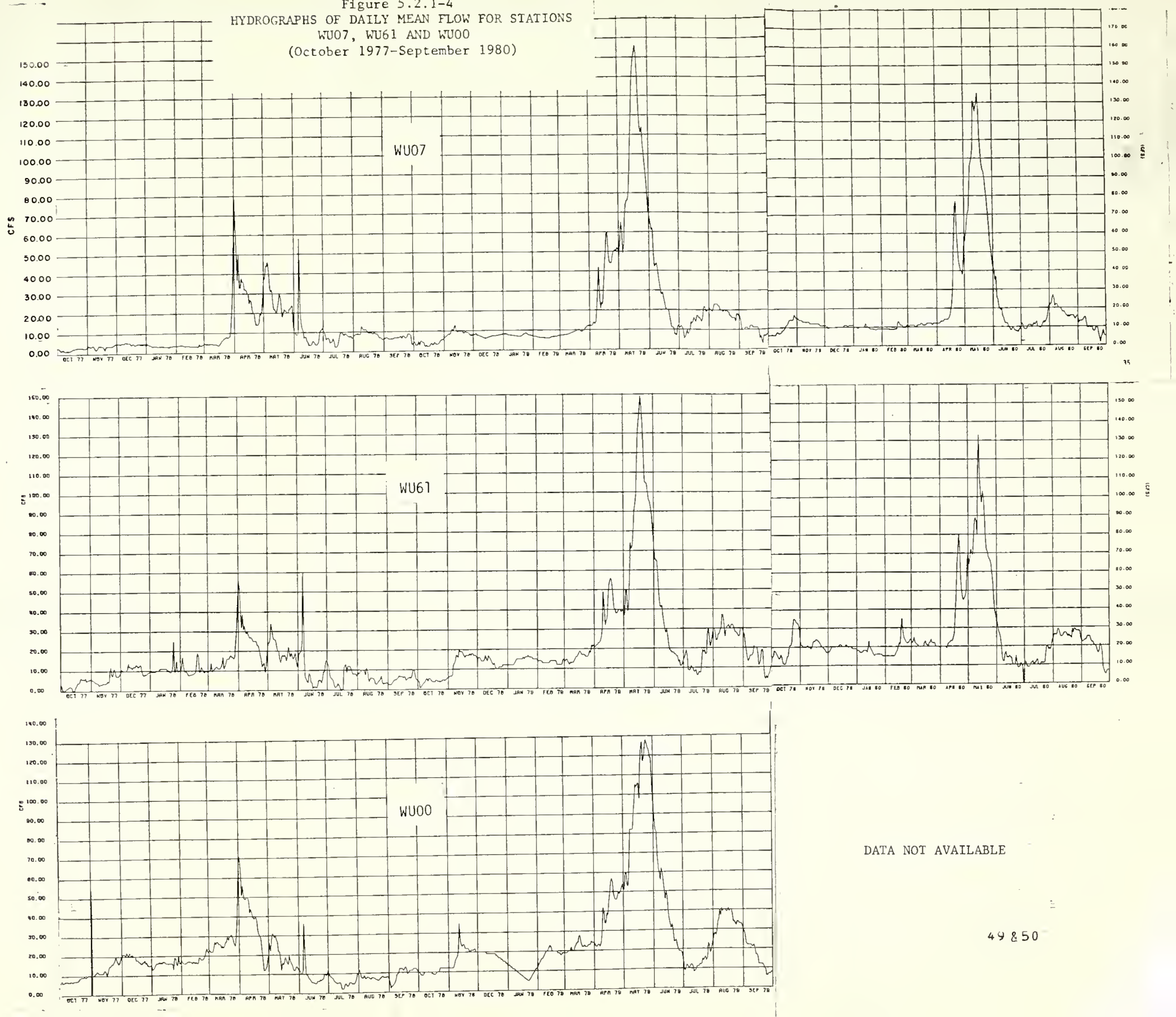


Figure 5.2.1-4
HYDROGRAPHS OF DAILY MEAN FLOW FOR STATIONS
WU07, WU61 AND WU00
(October 1977-September 1980)



49 & 50

Total annual and mean daily stream flows for stations WU07, WU61, WU00, WU22, and WU58 are given in Table 5.2.1-2. These can be compared with the stream flow for 1980. The fall of 1979 and winter of 1979-1980 were exceptionally wet and several precipitation stations reported heavy precipitation events in May. The many storms account for part of the above average stream flow. On Piceance Creek, the 1979 and 1980 water years have exhibited the greatest annual flows on record. New maximum daily stream flow records were set at WU07, WU58, and WU61. The new maximum flows at WU07 and WU61 were recorded on May 17 and May 13. The Little Hills weather station recorded precipitation events in excess of 0.40 inches on May 1 (0.45 in.), May 7 (0.45 in.), May 11 (0.54 in.), and May 17 (0.47 in.). Meteorological station AB23 on the C-b Tract recorded 0.45 inches on May 11. According to these stations, May 1980 was a wet month but not as wet as April and May of 1979.

The new daily maximum flow at WU58 was recorded August 15. Meteorology station AB20 recorded 1.37 inches of precipitation in July and 0.86 inches in August, while station AB23 recorded 0.65 in July and 0.62 in August. The new minimum daily flow at WU58 was recorded on May 10 and minimum daily flows at WU07 and WU61 were recorded in September.

The ratio of flow at WU07 to that at WU61 was calculated for all years since 1974. The low was 0.50 in 1977 and the high was 0.89 in 1978. The ratio for 1980 was 0.76, i.e. the flow past WU07 averaged 72 percent of the flow past WU61.

Flow for 1980 at WU42, a new station measuring discharge from No Name Gulch, totaled 275.2 acre-feet, about 1 percent of the flow at WU61.

Trend analysis by means of the Box-Jenkins statistical analysis technique for flows at stations WU07 and WU61 concluded that no time trends exist in the data. Summaries of the Box-Jenkins analysis are included in the Appendix Volume 2A as Tables A5.2.1-1 and A5.2.1-2.

5.2.2 Springs and Seeps

5.2.2.1 Scope

The flow from natural springs and seeps provides a substantial fraction of the volumetric low-level stream flows to Piceance Creek. The source areas for the springs have not been documented, and the hydrologic relationships are imperfectly known. Although none of the springs studied are actually on the C-b Tract, all are close enough that they may or may not be affected by significant changes in the groundwater system caused by mining activities.

Through the baseline phase, flow data were obtained from nine springs located on the west and east boundary of the Tract and along Piceance Creek (Figure 5.2.2-1). Monitoring of three new additional springs was initiated to comply with the Water Augmentation Plan. The new springs are S-10A adjacent to S-10, S-101 in West Stewart Gulch, and S-102 on Piceance Creek, just

TABLE 5.2.1-2

TOTAL ANNUAL AND MEAN DAILY STREAM FLOW

Water Year	Station WU07		Station WU22		Station WU58		Station WU61		Station WU00	
	Total Ac-ft/yr	Mean cfs	Total Ac-ft/yr	Mean cfs	Total Ac-ft/yr	Mean cfs	Total Ac-ft/yr	Mean cfs	Total Ac-ft/yr	Mean cfs
1975	9,651	13.3	1,448	2.0	1,448	2.0	13,180	18.2	20,994	29.0
1976	7,245	10.0	1,304	1.8	1,738	2.4	12,022	16.6	18,099	25.0
1977	3,632	5.0	1,014	1.4	1,014	1.4	7,170	9.9	9,412	13.0
1978	6,995	9.7	869	1.2	784	1.0	7,894	10.9	11,584	16.0
1979	14,991	20.7	869	1.2	960	1.3	17,743	24.5	20,994	29.0
Average	8,502	11.7	1,101	1.5	1,159	1.6	11,609	16.0	16,217	22.4
1980	14,507	20.3	1,347	1.9	2,890	4.0	19,141	26.4		

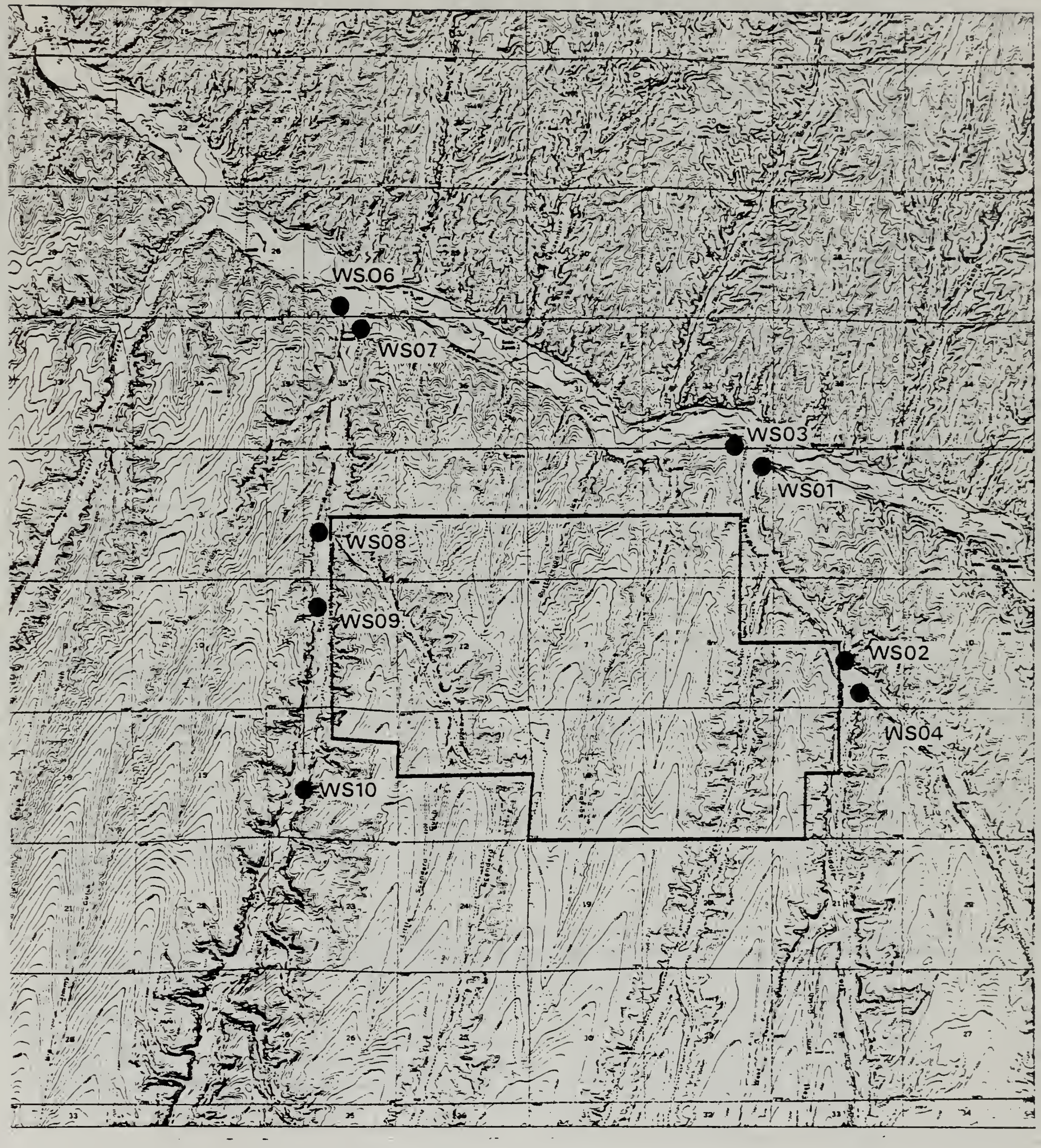


FIGURE 5.2.2-1a SPRINGS AND SEEPS MONITORING NETWORK NEAR TRACT

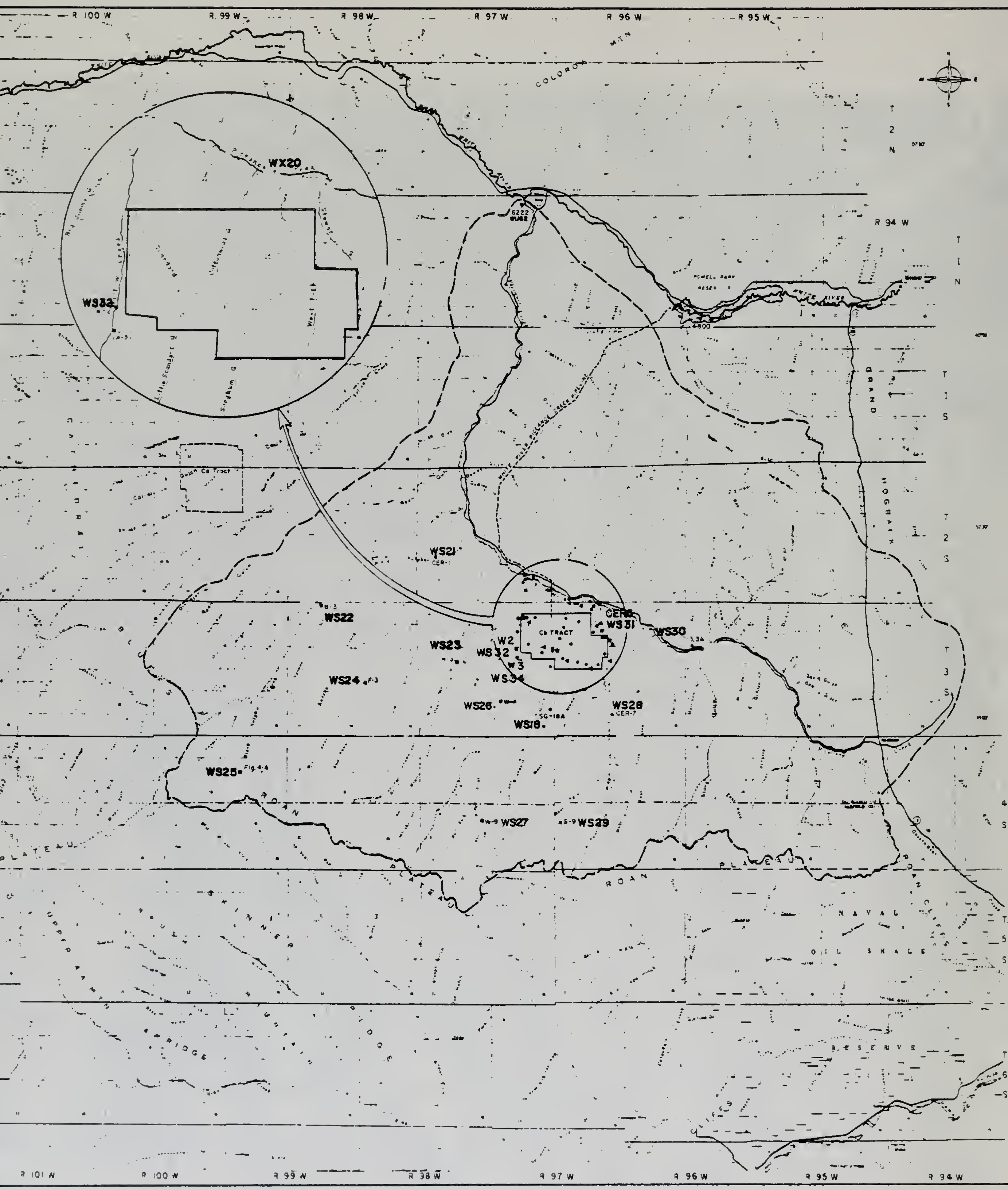


FIGURE 5.2 2-1b
SPRINGS AND SEEPS MONITORING NETWORK
OFF TRACT

downstream from the confluence of No-Name Gulch and Piceance Creek (Figure 5.2.2-1).

Figure 5.2.2-2 shows the springs and seeps identification numbers and the sampling schedule for measurement of flows.

Precipitation data have been gathered at meteorological stations both on and immediately off the Tract and used for comparison with spring flows.

5.2.2.3 Experimental Design

The design concept is to measure the flow of springs and seeps on a weekly schedule throughout the year, and to use the data produced to attempt to determine the location of source areas for springs. If the source were proximal, precipitation on or near the Tract should be reflected quite rapidly in the spring outflow. In addition, periods of little or no precipitation or drought conditions should cause reduction in spring flows.

5.2.2.4 Methods of Analysis

Correlations were made between precipitation data and flows from individual springs. In addition, spring flows have been examined statistically by linear regression analysis to identify linear trends over time that may exist. This analysis was performed both on a long-term basis using baseline and subsequent data, and on a short-term basis using data for the 1980 water year.

5.2.2.5 Discussion and Results

Total monthly precipitation at two meteorology stations, AB20 and AB23, was plotted against average monthly flow from each of five representative springs (WS01, WS02, WS03, WS06, WS09). Linear regression analysis of these two variables showed that no correlation exists for either long-term or short-term flows. The values for each correlation are presented in Table 5.2.2-1.

The results of the correlations at some springs are not surprising. For example, the time-series pattern for spring WS09 (Figure 5.2.2-3) is so consistent as to suggest a recharge area some distance away. However, because WS09 rises through the alluvium, it is possible that extremes dampened.

Flow data from some springs are suspect for reasons described below and correlation between some springs with on-Tract precipitation should be considered tentative until the data are certified. For example, springs WS01 and WS03 are used for irrigation. The flume for WS03 receives return flow from WS01 which is diverted into the field above its flume. Hence during periods of irrigation, measurements at the flume for WS01 will be lower than normal and measurements at the flume for WS03 will be correspondingly higher. This relationship can be seen in Figure 5.2.2-4 which is a graph of flows from these two springs. Without interfering with the agricultural

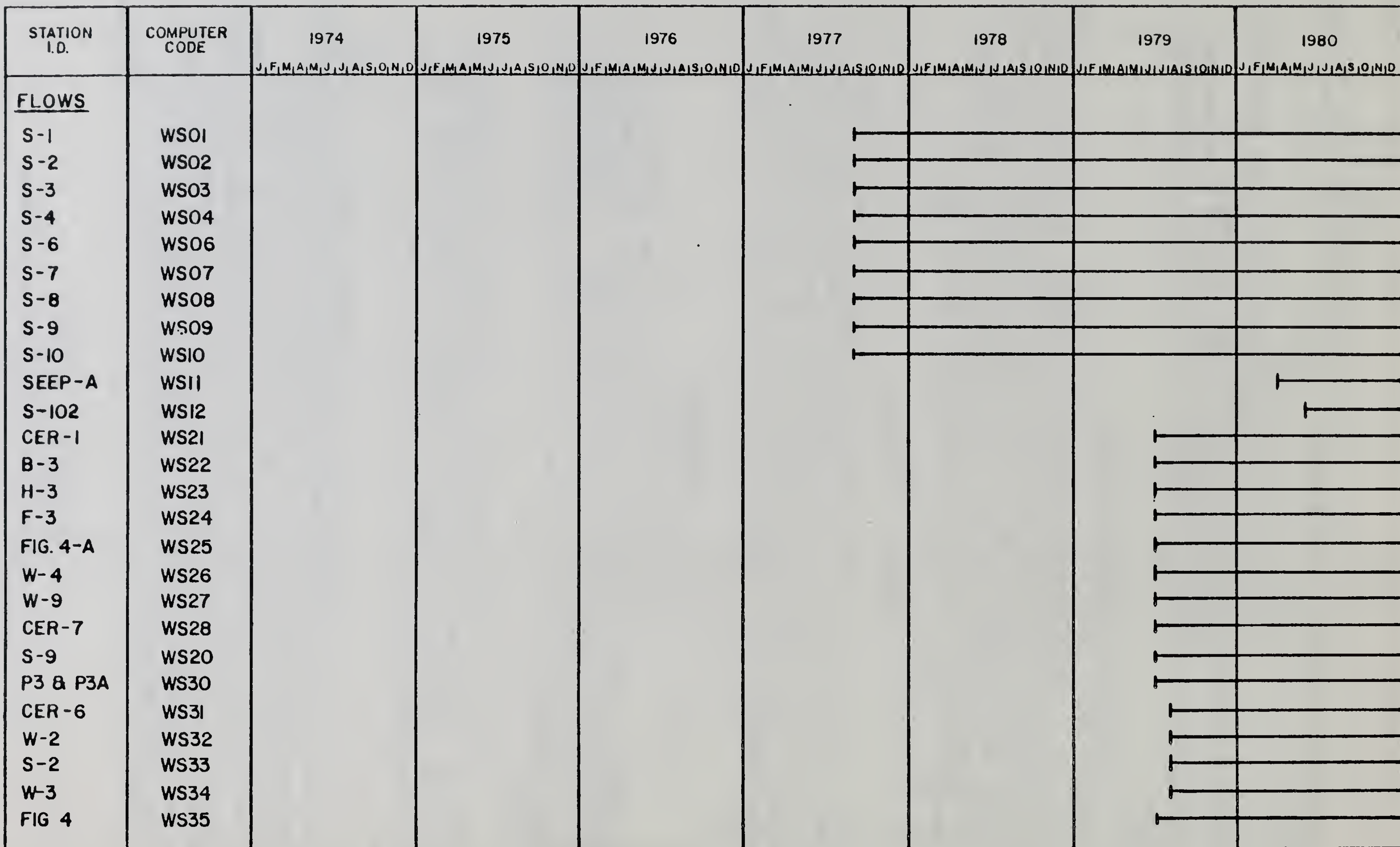


FIGURE 5.2.2-2
SPRINGS AND SEEPS SAMPLING TIME INTERVALS FOR FLOWS

TABLE 5.2.2-1

Long-Term and Short-Term Correlations
Between Precipitation and Spring Flow

Spring	Meteorology Station	n*	$\hat{\alpha}$**	
WS01	AB23	33	0.3110	No Correlation
	AB20	33	0.3733	"
	AB23	12	0.3939	"
	AB20	12	0.9215	"
WS02	AB23	29	0.1048	No Correlation
	AB20	29	0.3045	"
	AB23	11	0.6675	"
	AB20	12	0.6133	"
WS03	AB23	29	0.7219	No Correlation
	AB20	20	0.9110	"
	AB23	10	0.6352	"
	AB20	10	0.9928	"
WS06	AB23	35	0.5392	No Correlation
	AB20	34	0.5597	"
	AB23	11	0.2243	"
	AB20	10	0.1044	"
WS09	AB23	37	0.9967	No Correlation
	AB20	37	0.9458	"
	AB23	12	0.4187	"
	AB20	11	0.1755	"

* $n \leq 12$ identifies short-term analysis.

** $\alpha \leq 0.05$ implies correlation at 5% level of significance.

FIGURE 5.2.2 – 3

WATER FLOWS FOR SELECTED SPRINGS

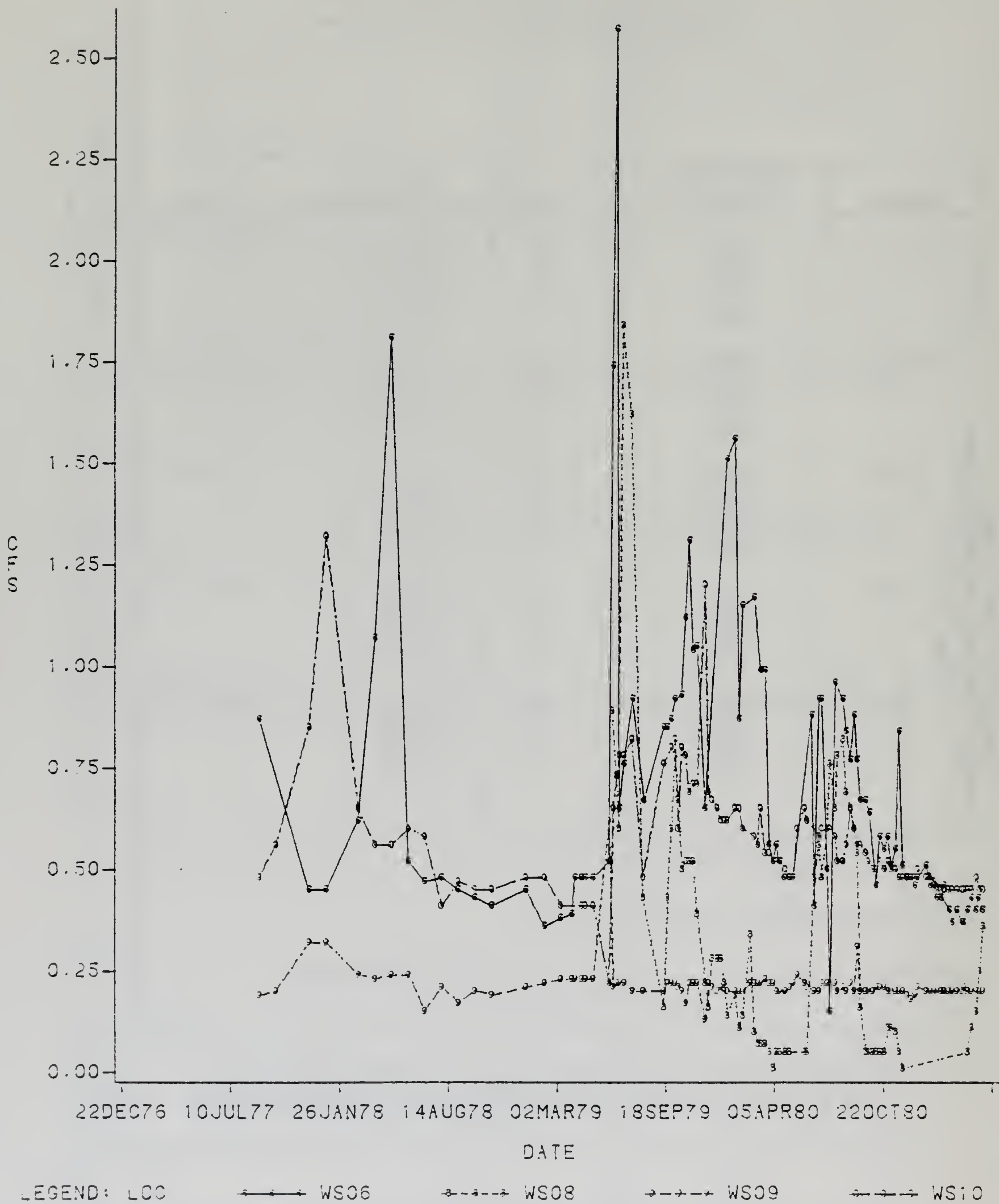
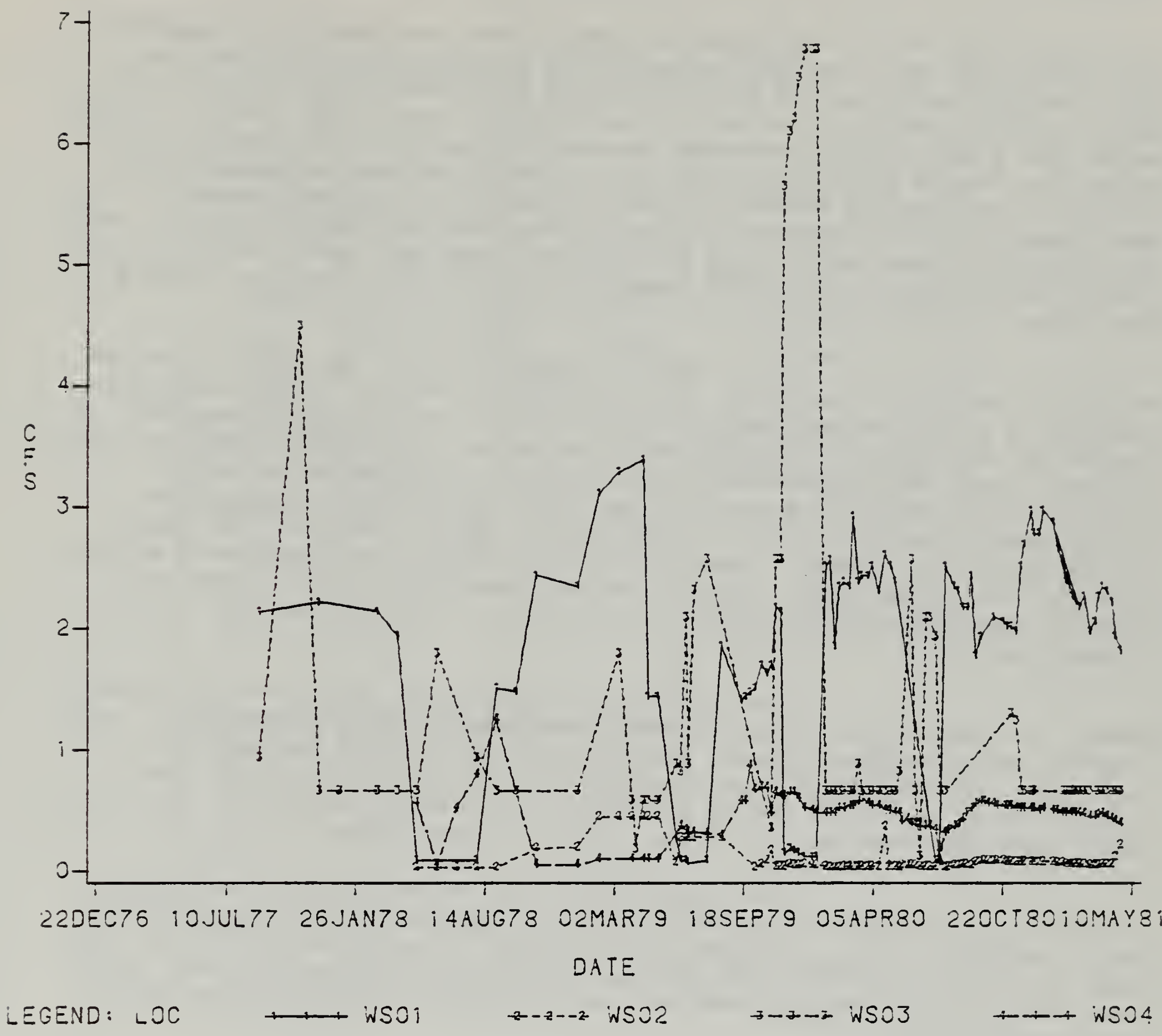


FIGURE 5.2.2 – 4

WATER FLOWS FOR SELECTED SPRINGS



practices of the site, normal flow patterns for these springs cannot be established.

Of the other springs near the Tract, only flow data from WS02, WS04, WS09, and WS12 are certified as reliable through baseline. Data from WS06 was skewed by local irrigation practices but should be reliable since the installation of the second flume (06A) in June, 1980. WS07 is believed to have a leaking pond, therefore the reliable period of this spring is not known. The flow in spring WS08 appears to be receiving some influence through fractures from a nearby irrigation canal. Problems in flow measurements at WS10 were caused by winds from certain azimuths. The wind appeared to cause the water to accumulate at the mouth of the flume giving incorrect levels. The installation of an additional flume, WS36, should provide correct flow data for WS06 in the future.

Tables A5.2.2-1 and A5.2.2-2 in the Appendix are the results of the initial screening of flow data for trends by linear regression analysis at a five percent level of significance. Table 5.2.2-2 summarizes the results of the analysis. Problems described above indicate that long term trend analysis should be considered tentative except for WS02, WS04, and WS09. Figures 5.2.2-3 and 5.2.2-4 include flow data for these three springs from initial data collection through October, 1980. None of the data from these springs show linear trends. General linear analysis was also performed on data from WS01, WS03, and WS06. Both WS03 and WS06 exhibited linear trends, but based on the foregoing discussion, this statistical manipulation must be considered tenative.

From a statistical standpoint, to say that a linear model fits certain data or has a linear trend implies certain conditions, limitations, and assumptions, one of which is that the slope of the model is other than zero. The pattern of flows from WS04 and WS09 appear linear (Figures 5.2.2-3 and 5.2.2-4) even though the slopes of the models were zero. This would explain why the linear model did not fit the long-term data.

The linear model fits the short-term data for most of the springs. The linear model did not fit the short-term flow data from WS02, and as explained above, the reason could be that the slope was zero. The linear model did not fit the flow from WS12 and WS36 because the number of data points were insufficient. Fewer data points require greater r-value to show statistical significance.

The ability to recognize trends is important in monitoring the development activities on the C-b Tract. However, there are problems associated with analyzing trends of hydrologic data in the Piceance Creek Basin. For example, on 17 May 1973, the Rio Blanco nuclear test occurred about eight miles west of the C-b Tract. There was an immediate increase in flows from springs and in some instances, flows doubled. The increase in stream flow attributed to the nuclear test was discussed at length in the Final Report of the Environmental Baseline Program (Vol. 2, page 35, ff) and will not be discussed here. It would be difficult to say with any degree of certainty that a decrease in flow from a certain spring is attributable to Tract C-b activities or a normal return to natural conditions following the Rio Blanco Test.

TABLE 5.2.2-2

Summary of Short-Term and Long-Term Linear Regression Analysis for Selected Springs, Tract C-b

Station (Springs)	n*	$\hat{\alpha}$**	Slope Cfs/mo.	Existence of Trend
				Long-Term
WS02	45	0.3137	0.00008	No Linear Trend
WS09	43	0.1482	0.00005	No Linear Trend
C.B. Springs				Short-Term
WS02	12			No Linear Trend
WS04	12	0.02	0.00006	Linear Trend
WS09	12	0.007	0.0019	"
WS36	7			No Linear Trend
WS12	4			No Linear Trend
Selected Water Augmentation Springs				
WS22	12	0.003	0.0006	Linear Trend
WS23	12	0.01	0.0044	"
WS24	12	0.03	0.003	"
WS27	12	0.04	0.0005	"
WS31	12	0.03	-0.0016	"
WS34	12			No Linear Trend

* $n \geq 12$ implies long-term data; $n \leq 12$ implies short-term data.

** $\alpha \leq 0.05$ implies a linear trend.

In summary, correlations between precipitation at C-b meteorology stations and flow from springs do not exist. This would imply that events that occur on the surface of the Tract do not have a major effect on flow from the springs. As shown by general linear modeling, long-term linear trends do not exist.

General linear modeling indicates a trend for average monthly flow over the past year. The slope of each regression line is small (none are greater than 0.003). Of ten springs, five show positive slope and five show negative slope.

Considering these analyses, it currently appears that there is no significant effect of development activities on spring flow. However, the data may be masked by the Rio Blanco Nuclear Test of 1973.

5.2.3 Alluvial Wells

5.2.3.1 Scope

The Development Monitoring Plan discusses the fourteen alluvial monitoring wells. The well locations are shown in Figure 5.2.3-1. Figure 5.2.3-2 shows the sampling intervals for each well.

5.2.3.2 Objectives

The present objective of monitoring the water level in each alluvial well is to detect changes in the water levels in the alluvium of Piceance Creek and its tributaries that are on or adjacent to the Tract, and if significant changes are attributable to activities on Tract C-b.

5.2.3.3 Experimental Design

Monthly measurements of water levels in the alluvial wells were continued during 1980. The data were subsequently analyzed according to methods described in 5.2.3.4

5.2.3.4 Method of Analysis

A general linear regression model was applied to water level data from the wells shown in Figure 5.2.3-2. Time series plots of the water levels in each well were prepared and qualitatively analyzed.

5.2.3.5 Discussion and Results

The time series plots of water levels for each well are shown in the Appendix. Alluvial well WA04 in Scandard Gulch remained dry; a water level has never been recorded in this well. Data from WA07 and WA10 are intermittent. In most instances, interruptions in data gathering are attributed to malfunctions in the continuous recorders in the alluvial wells. WA10, however, was obstructed and collection of data was not possible.

Since the fall of 1974, no significant changes in either water levels or variability of levels can be observed (Figures 5.2.3-3

FIGURE 5.2.3-1
ALLUVIAL AQUIFER MONITORING NETWORK

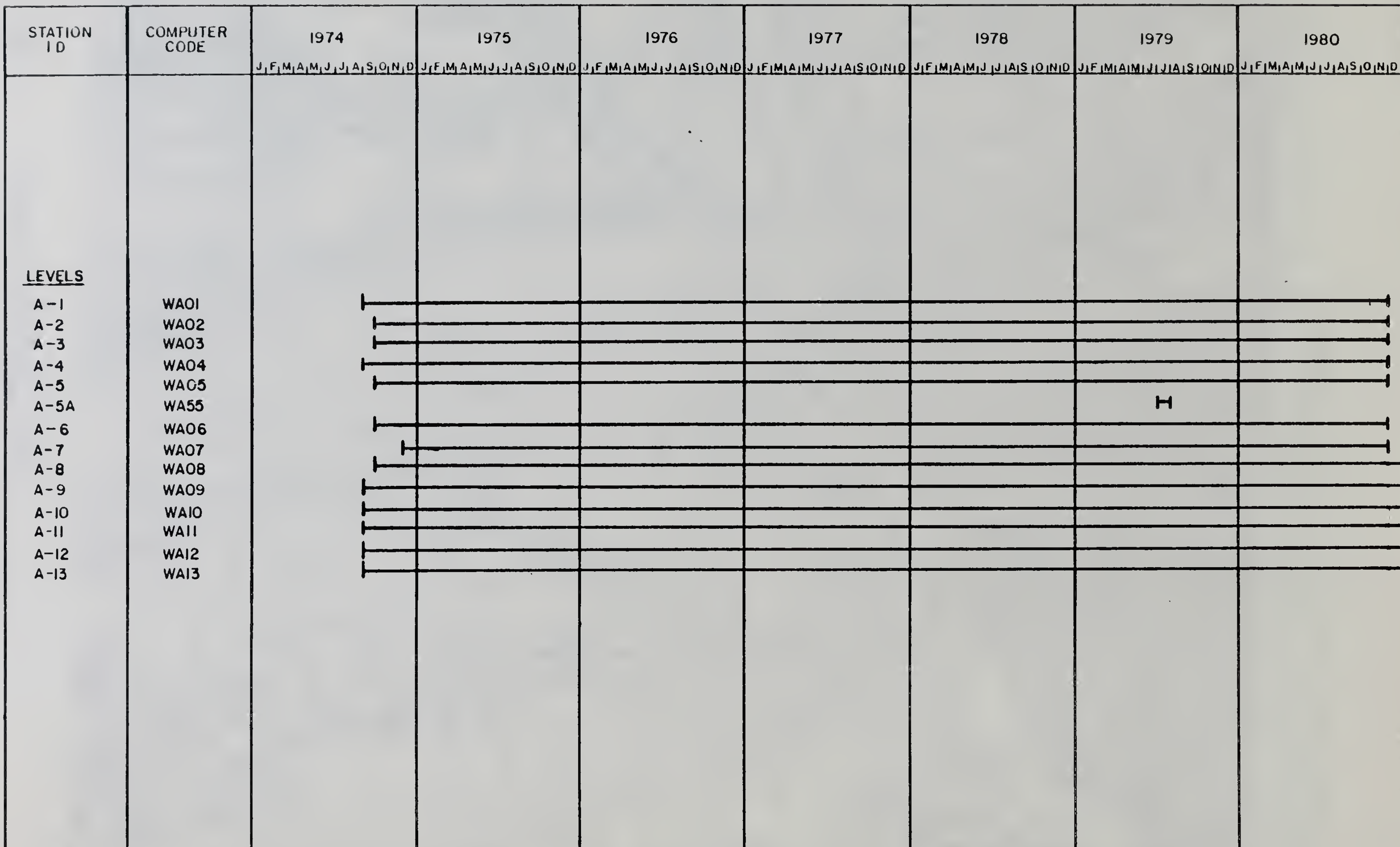
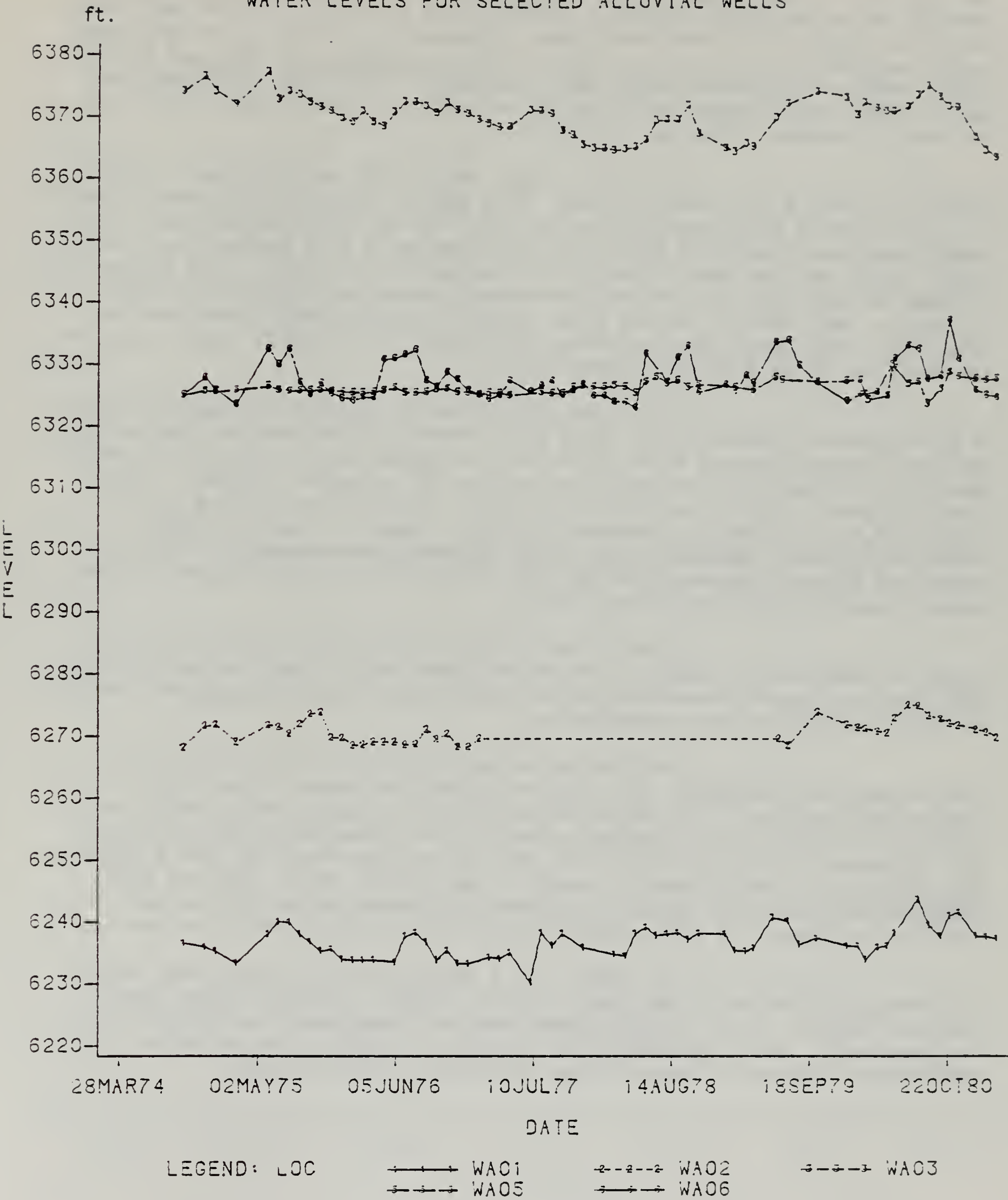


FIGURE 5.2.3-2
ALLUVIAL WELLS SAMPLING TIME
INTERVALS FOR LEVELS

FIGURE 5.2.3 – 3

WATER LEVELS FOR SELECTED ALLUVIAL WELLS



and 5.2.3-4). Linear regression, both long-term and short-term, was used to identify the potential existence of trends (Table 5.2.3-2). For the wells where short-term analyses of levels were made, there were no trends. On a long-term basis, negative linear trends existed at WA03, WA10, WA11, and WA12 and positive linear trends were found at WA01, WA02, and WA05. All of the trends were very small. Water level ranges in individual wells did not exceed eleven feet for the year. The modal value was five feet.

Wells WA01, WA02, WA03, WA06, and WA07 show a similar pattern (Figures 5.2.3-3 and 5.2.3-4). Only WA01 is actually on Piceance Creek. The others are on tributaries but within the alluvium of Piceance Creek. The yearly range was about five feet in all of these wells with maximum level in the summer months and the lowest levels in winter and early spring. This pattern is the same as that described in the Environmental Baseline Program Final Report (cf p157). Well WA08 in Stewart Gulch showed a range of about three feet in water level with the highest occurring in winter. The smallest range, less than two feet, was in WA12 in West Stewart Gulch.

Of all the alluvial wells, WA03 is the one most likely to be affected by dewatering if there were interaction between the deep bedrock and the alluvium, because it is closest to and approximately aligned with the developing northwesterly extension of the cone of influence. However, inspection of Figure 5.2.3-3 shows that the curve is negative from as long ago as March 1974 up to August or September of 1978. Since then there has been a strong rising trend through the time that dewatering has occurred. This is a strong and dramatic statement of the lack of interrelationship between the deep bedrock dewatering and the alluvial wells.

Alluvial wells WA11 and WA12 are farthest from the center of dewatering. However, some of the nearer wells (WA06 and WA07) do not show negative trends. Therefore, it is very unlikely that the negative trends for WA11 and WA12 are due to dewatering.

Analyses of the water levels in the alluvial wells with respect to development activities revealed no evidence of any effect. Spatial distribution of the wells and the plots of recorded water levels would indicate that there are no apparent effects of mine dewatering and discharge. This statement is strengthened by the observation that there has been a significant decrease in the piezometric levels in two bedrock wells, SG20 and SG19 (WX20 and WX19) while no decrease occurred in alluvial wells WA06 and WA07, less than 100 feet away. In fact, water levels in both wells slightly increased.

In summary, on a short-term basis, the linear model fits none of the alluvial well data. There are some long-term trends with a slightly negative slope, however these negative slopes began during baseline for some wells. Most importantly, there does not appear to be any effect of dewatering on the water levels in the alluvium of Piceance Creek.

FIGURE 5.2.3 – 4

WATER LEVELS FOR SELECTED ALLUVIAL WELLS

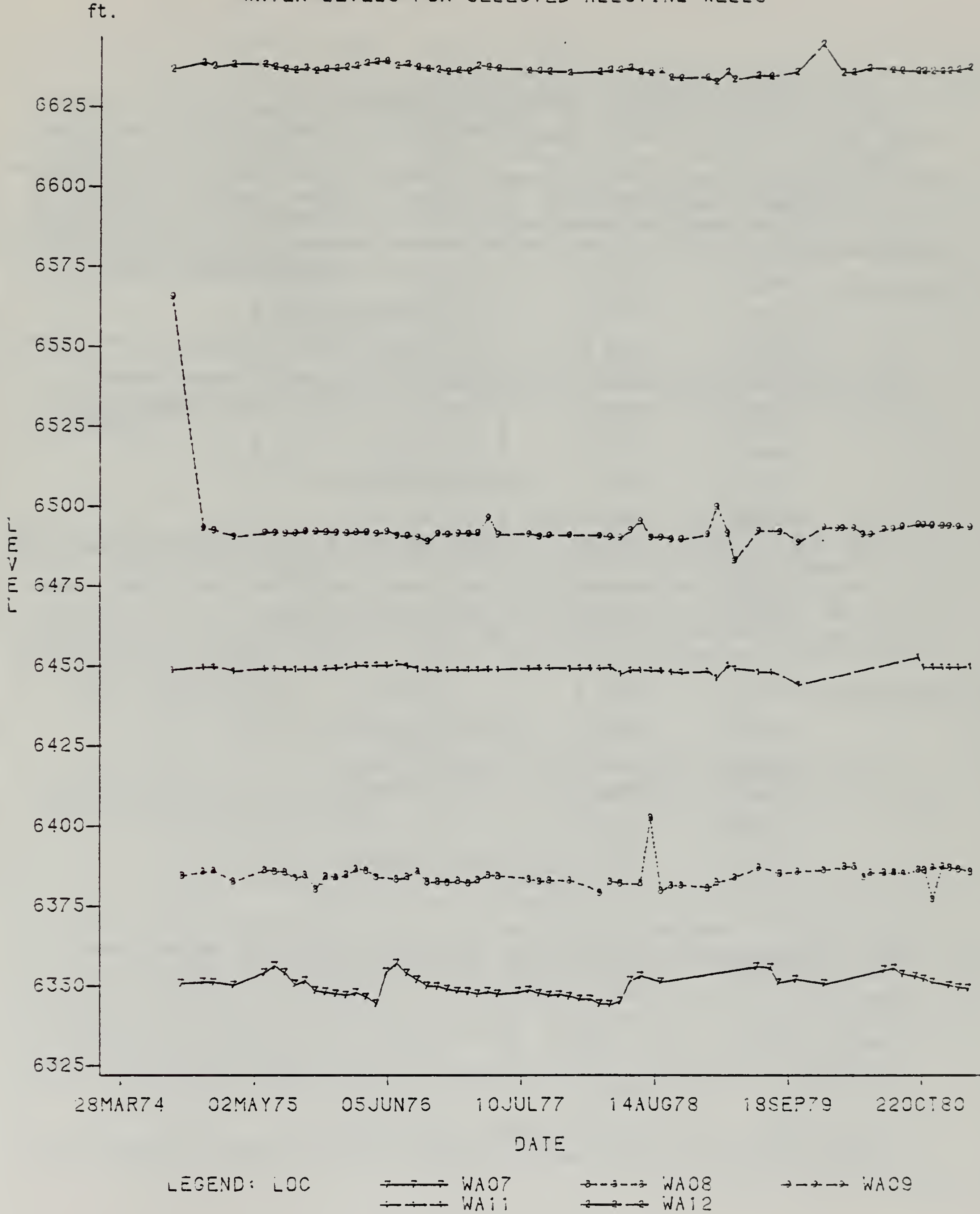


TABLE 5.2.3-2

SELECTED STATISTICS GENERATED IN LINEAR REGRESSION
OF ALLUVIAL WELL WATER LEVELS vs. TIME

	Well No.	Mean Water Level Elev (ft) Above S.L.	n	$\hat{\alpha}$ *	Slope ft/month	Linear Trend Test
Long Term Analysis	WA01	6236.4	55	0.006	0.0014	Linear Trend
	WA02	6270.6	36	0.008	0.0012	"
	WA03	6370.2	60	0.048	-0.0013	Negative Linear Trend
	WA05	6326.1	56	0.000	0.0007	Linear Trend
	WA06	6327.5	59	0.137	-	No Linear Trend
	WA07	6349.8	50	0.473	-	"
	WA08	6384.1	52	0.463	-	"
	WA09	6492.9	55	0.116	-	"
	WA10	6562.8	45	0.000	-0.0036	Negative Linear Trend
	WA11	6449.0	51	0.031	-0.0006	"
	WA12	6637.0	55	0.040	-0.0008	"
Short Term Analysis	WA01	6237.9	7	0.108		No Linear Trend
	WA02	6272.9	8	0.346		"
	WA03	6372.7	8	0.902		"
	WA05	6326.5	7	0.320		"
	WA06	6327.7	7	0.192		"
	WA12	6638.0	7	0.521		"

* $\hat{\alpha}$ less than 0.05 indicates a linear trend at the 5 percent level of significance.

5.2.4 Upper Aquifer Wells

5.2.4.1 Scope

As in other parts of the hydrologic program, the scope of the Upper Aquifer monitoring program is to determine effect of Tract development on the hydrologic system in the Upper Aquifer. The sinking of three shafts on Tract was initiated in 1979 and dewatering was required as the shafts were sunk. The removal of the estimated quantities of water will have an effect on the upper aquifer. The wells monitoring the upper and lower aquifers are shown in Figures 5.2.4-1 and 5.2.4-2. The wells in the latter figure are those added to the scope of the deep well monitoring program by the Water Augmentation Plan and Court Decree (W3492).

5.2.4.2 Objectives

The objectives of this Upper Aquifer monitoring program are to determine potential for perturbations that might be caused by Project development and to ascertain the effects of dewatering during shaft and mine development.

5.2.4.3 Experimental Design

Water levels are sampled monthly at 28 upper aquifer wells. Figure 5.2.4-3 is a list of these wells and the length of their data base. The experimental design is to assess potential significant changes in water levels over time. The accuracy of these data depends upon the method of measurement; that is, minimizing outside influences on the particular well being measured. For example, withdrawing an adequate sample for water quality analysis disturbs the water level in the well, and the rate of return to equilibrium conditions is different for each well.

5.2.4.4 Method of Analysis

Tabular averages, plots and linear regression were used in the analysis. The general linear regression model was employed for both short-term and long-term trends.

5.2.4.5 Discussion and Results

Of the C-b Tract wells, the only water level which did not decline was in WX10 and, in fact, its water level increased (Table 5.2.4-2). The trend, however, was not significant. The largest decreases in water levels occurred in those wells closest to the shafts, as expected. There was a decrease of 160 feet in the water level at WX33 near the V/E shaft. Water levels in WX32, near the Service/Production shafts, decreased about 275 feet. Declines elsewhere on the Tract varied from four feet in WX17 in the southeast corner to about 70 feet in WX02 near the north boundary of the tract between Sorghum and Cottonwood Gulches. See Figure A5.2.4-1 for water level plots.

Off-Tract monitoring wells including those listed under the Water Augmentation Plan showed declines based on proximity to the

FIGURE 5.2.4-1
DEEP WELL MONITORING NETWORK
C-b TRACT

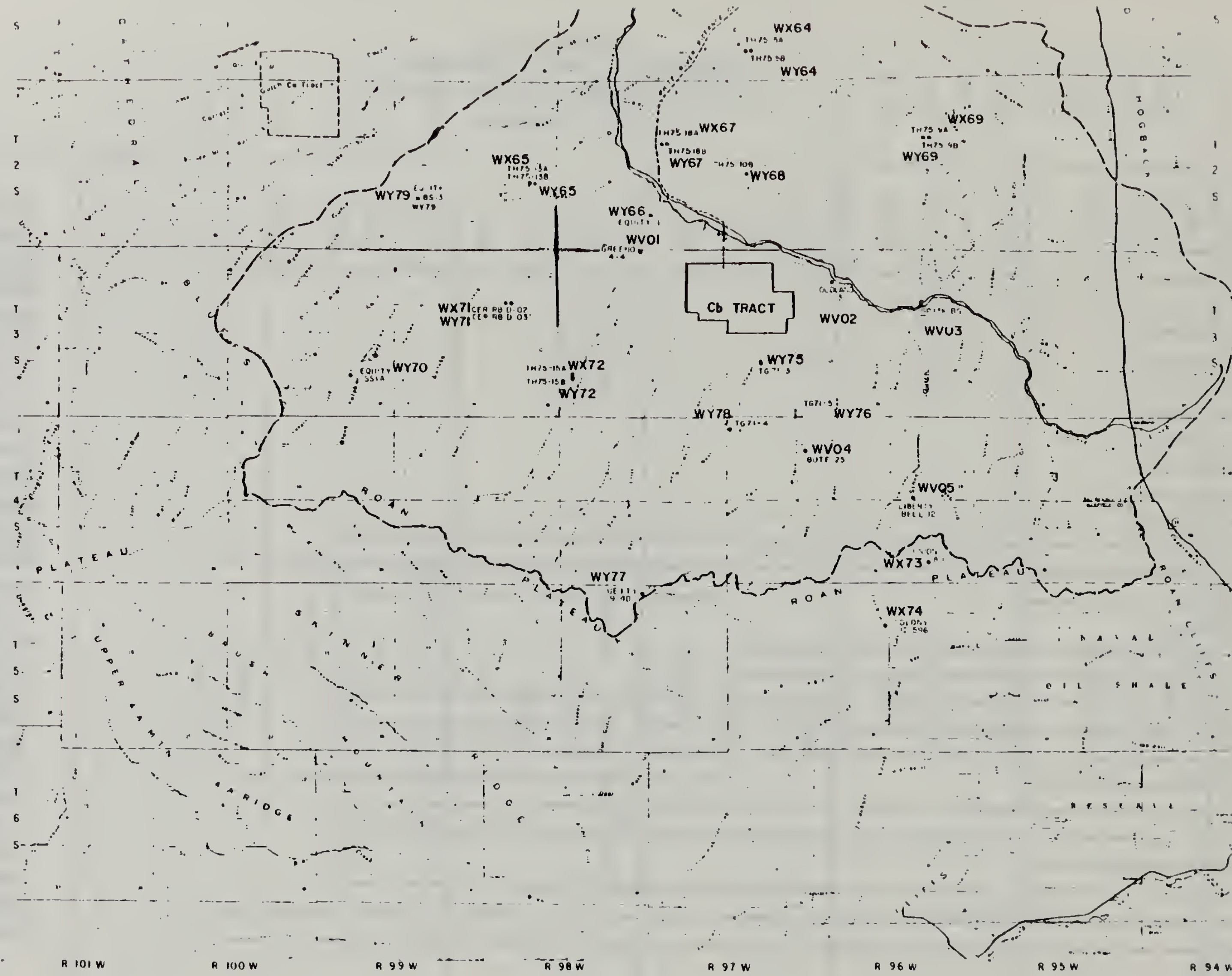


Figure 5.2.4 - 2. · DEEP WELL MONITORING NETWORK OFF-TRACT

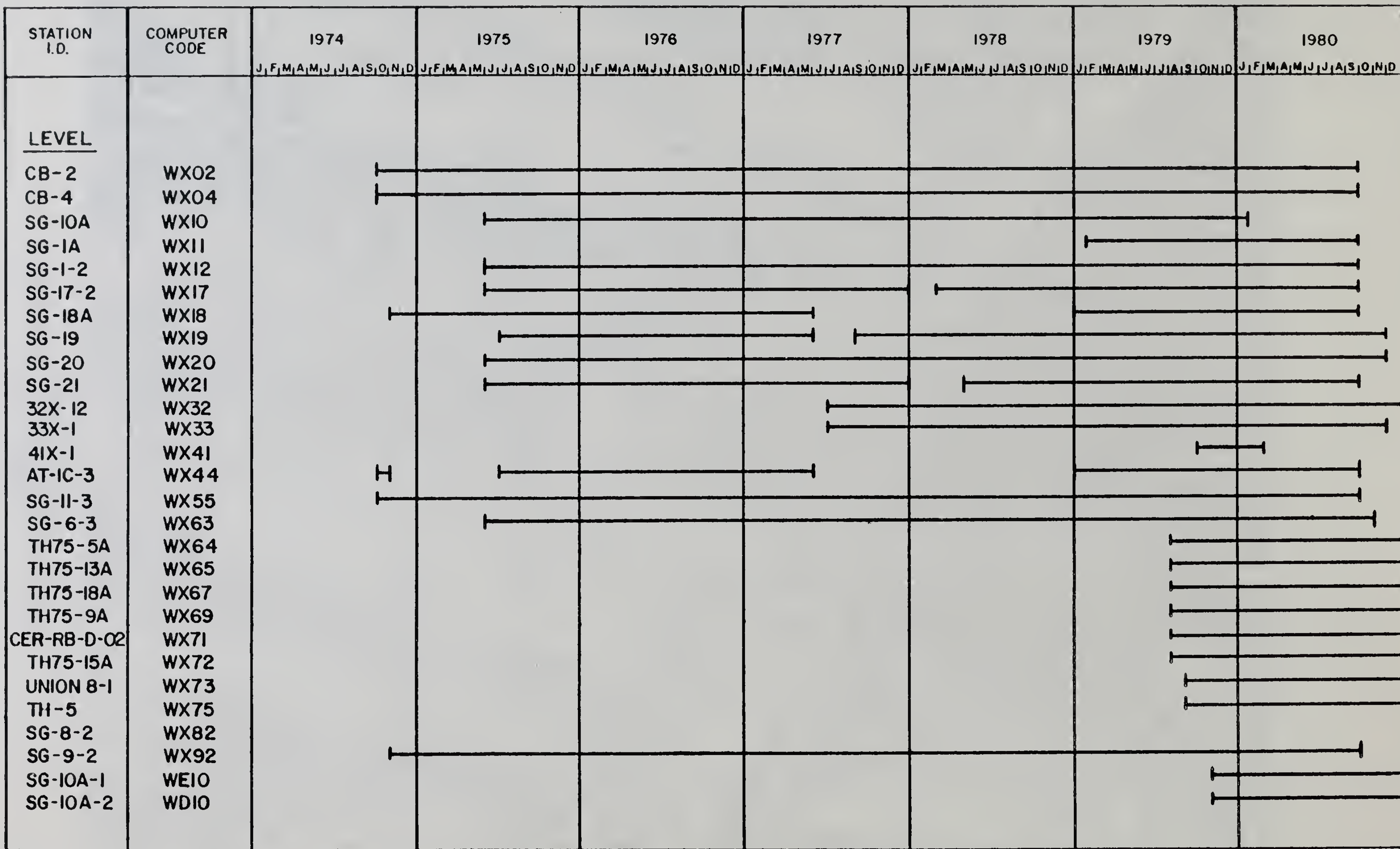


FIGURE 5.2.4-3
UPPER TRACT AQUIFER WELLS
SAMPLING TIME INTERVALS
FOR LEVELS

TABLE 5.2.4-2

Upper Aquifer Wells

Short-Term Data 1980

Well	Approx. Mid Year Elevation (ft)		Direction of Change	Approx. Change (ft)
WX02	6360		Decrease	-70
WX04	6625		Decrease	-15
WX10	6570		Increase	15
WX11	-		-	
WX12	6350		Decrease	-20
WX14	-		-	
WX17	6636	Corrected	Decrease	- 5
WX18	6900		None	-
WX19	6345		Decrease	-55
WX20	6310		Decrease	-90
WX21	6700		None	-
WX32	6300		Decrease	-275
WX33	6250		Decrease	-160
WX44	6500		Decrease	80
WX55	6555	Corrected	Increased, then decreased	10 ± 5
WX63	6530	Corrected	Decrease	30
WX64	6760		Increase	5
WX65	6332		Increase	1
WX67	6308		Decrease(Decreased 1 ft. in March, then recovered	0.5
WX69	6897		None	-
WX72	6760		Increased(Decreased, then increased)	3
WX73	6757		None	
WX75			None	
WX92	6520	Corrected	Decrease	10

shafts. WX21, located south of the Tract on Scandard Gulch, began declining very slightly late in the water year, with a total decline of about two feet. The trend in WX21 was not significant. Wells WX19 and WX20 are both about one-half mile north of the tract. A decline of about 55 feet was recorded in WX19, and the water level in WX20 dropped about 90 feet.

No wells further than two miles from the Tract center showed decreases in water levels. Some wells, for example WX67, WX72, WX64, showed slight rises in water levels on the order of one foot. WX73 and WX75 showed no changes.

The general linear regression model was used in correlating water level measurements made in the 1980 water year with time. Table 5.2.4-3 presents the results of this correlation. The short-term change in water levels does not show a linear trend in all wells. For some, the reason for not fitting the linear model is the lack of a sufficient number of data points.

The largest negative slopes, i.e. most rapid decline, are found in WX32 and WX33, as would be expected. Slopes and the amount of decline are about equal in WX44 (south of and up gradient from the shaft) and in WX20 (north of and down gradient from the Tract).

Using data from the Upper Aquifer wells, contour plots of the potentiometric surface were made beginning in October, 1974. In the early years there were only a few wells with data available to us. The majority of these wells were within the C-b tract, however WX21 and WX18 were not. The plots showed a potentiometric surface sloping to the north and a gentle axial high with a trend almost due north through the center of the Tract. North of the tract the surface showed a north-northwest trend. This configuration persisted through June of 1979 (Figure 5.2.4-4).

Beginning with the August 1979 plots, data became available to the northwest and north of Piceance Creek; from this time on, the contoured surface showed a strong northwesterly/southeasterly trend (see Figures 5.2.4-5 and 5.2.4-6). The surface plunges to the northwest with the axis of the trough cutting across the northwestern part of the Tract. The slight northward oriented bulge in the surface was still present. This configuration remained throughout the 1980 water year.

Two points are important here. The first is that the northwesterly trend of the surface became apparent in 1979, because for the first time data north of Piceance Creek were included. No data were available until October, 1979. The second point is that this northwest/southeast trend shows that the potentiometric contours did not wrap around Piceance Creek, but remained very close to the same direction of the cone of influence found in the C-a Tract.

Dewatering during shaft sinking and related mining activities during 1980 caused declines in levels of the upper aquifer monitoring wells near the shafts. Changes in levels between baseline and October 1979 are shown in Figure 5.2.4-7. Figure 5.2.4-8 shows the changes in levels between

TABLE 5.2.4-3

Water Levels - Upper Aquifer Wells

Results of General Linear Regression of Short-term Data 1980

Well No.	Mean Water Level*	n	$\hat{\alpha}$	Slope Ft. per mo.	R^2	
WX02	6357.1	10	0.0001	-0.203	0.974	Close fit - linear trend
WX04	6638.1	10	0.1348			No linear trend
WX10	6573.1	3	0.2314			No linear trend
WX11	5836.8	2				No linear trend
WX12	6346.7	11	0.001	-0.061	0.952	Close fit - linear trend
WX14	6500.4	2				No linear trend
WX17	6638.4	10	0.8193			No linear trend
WX18	6900.5	11	0.2953			No linear trend
WX19	6343.2	10	0.0001	-0.166	0.975	Close fit - linear trend
WX20	6315.7	10	0.001	-0.263	0.954	Close fit - linear trend
WX21	6711.6	11	0.1113			No linear trend
WX32	6287.9	7	0.001	-0.777	0.996	Best fit - linear trend
WX33	6231.7	7	0.003	-0.492	0.940	Close fit - linear trend
WX41	6437.8	2				
WX44	6505.4	10	0.0001	-0.268	0.890	Linear trend
WX55	6555.5	8	0.0986			No linear trend
WX63	6533.8	10	0.001	-0.084	0.946	Close fit - linear trend
WX64	6760.7	12	0.001	-0.014	0.976	Close fit - linear trend
WX65	6332.9	12	0.017	+0.004	0.450	Poor fit - pos. linear trend
WX67	6308.6	12	0.05915			No linear trend
WX69	6897.7	12	0.6318			No linear trend
WX72	6760.1	12	0.0215	+0.007	0.426	Poor fit - pos. linear trend
WX73	7649.7	12	0.4974			No linear trend
WX75	7516.7	10	0.5582			No linear trend
WX92	6520.0	10	0.0001	-0.0279	0.885	Close fit - linear trend

* Elevation in feet above sea level.

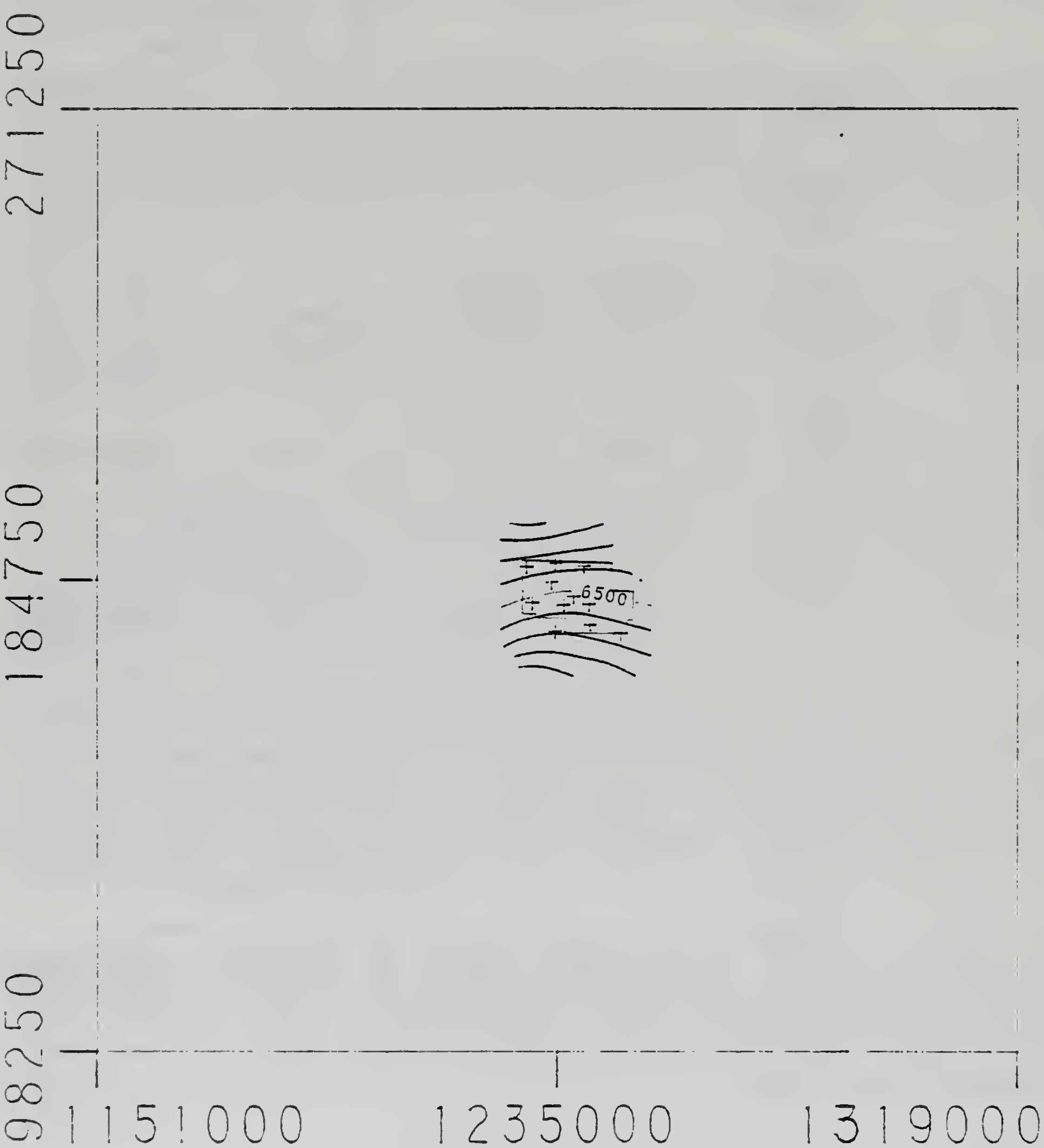


Figure 5.2.4-4
Potentiometric Surface for
Upper Aquifer Wells
June, 1979

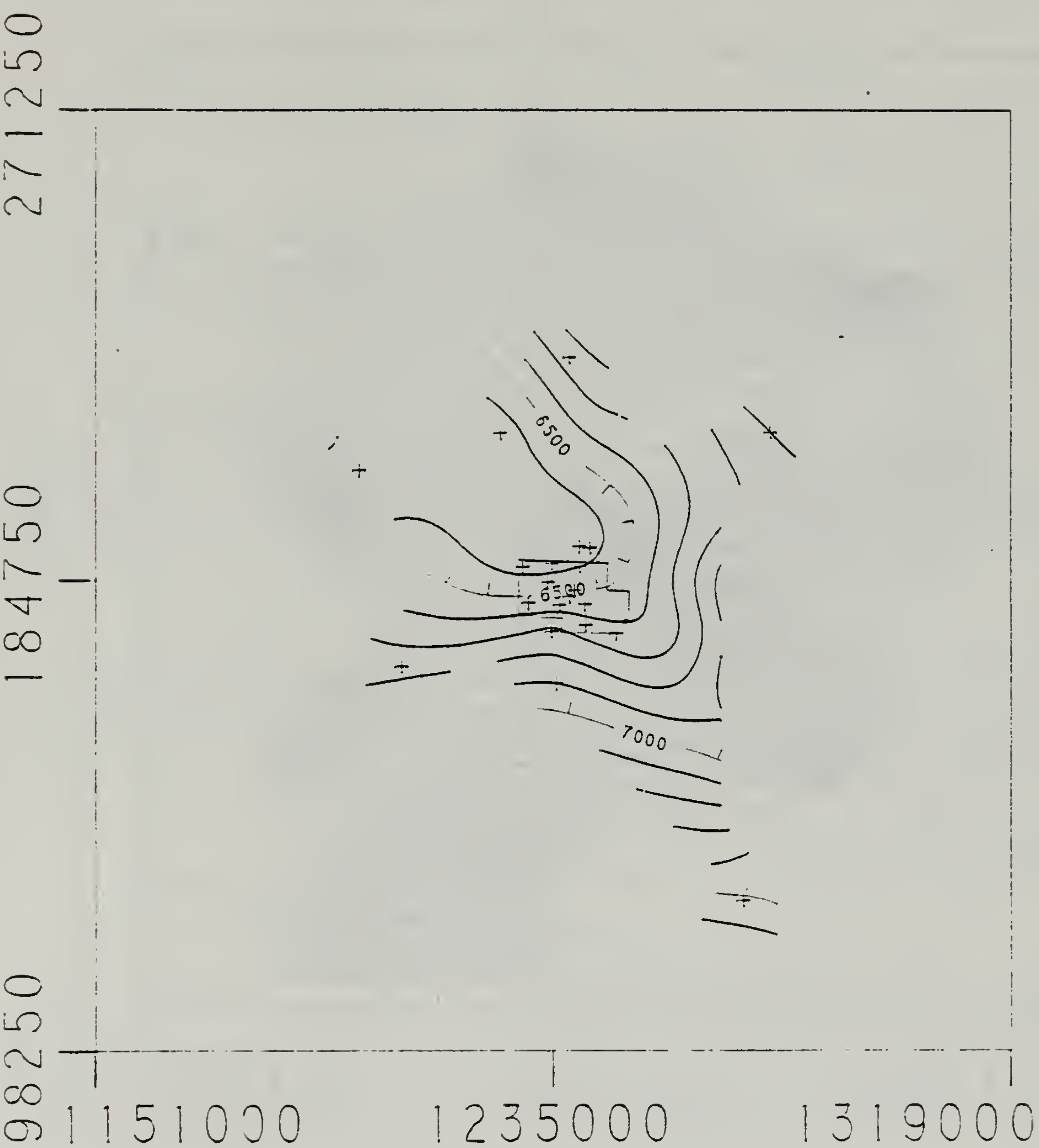


Figure 5.2.4-5
Potentiometric Surface for
Upper Aquifer Wells,
October, 1979

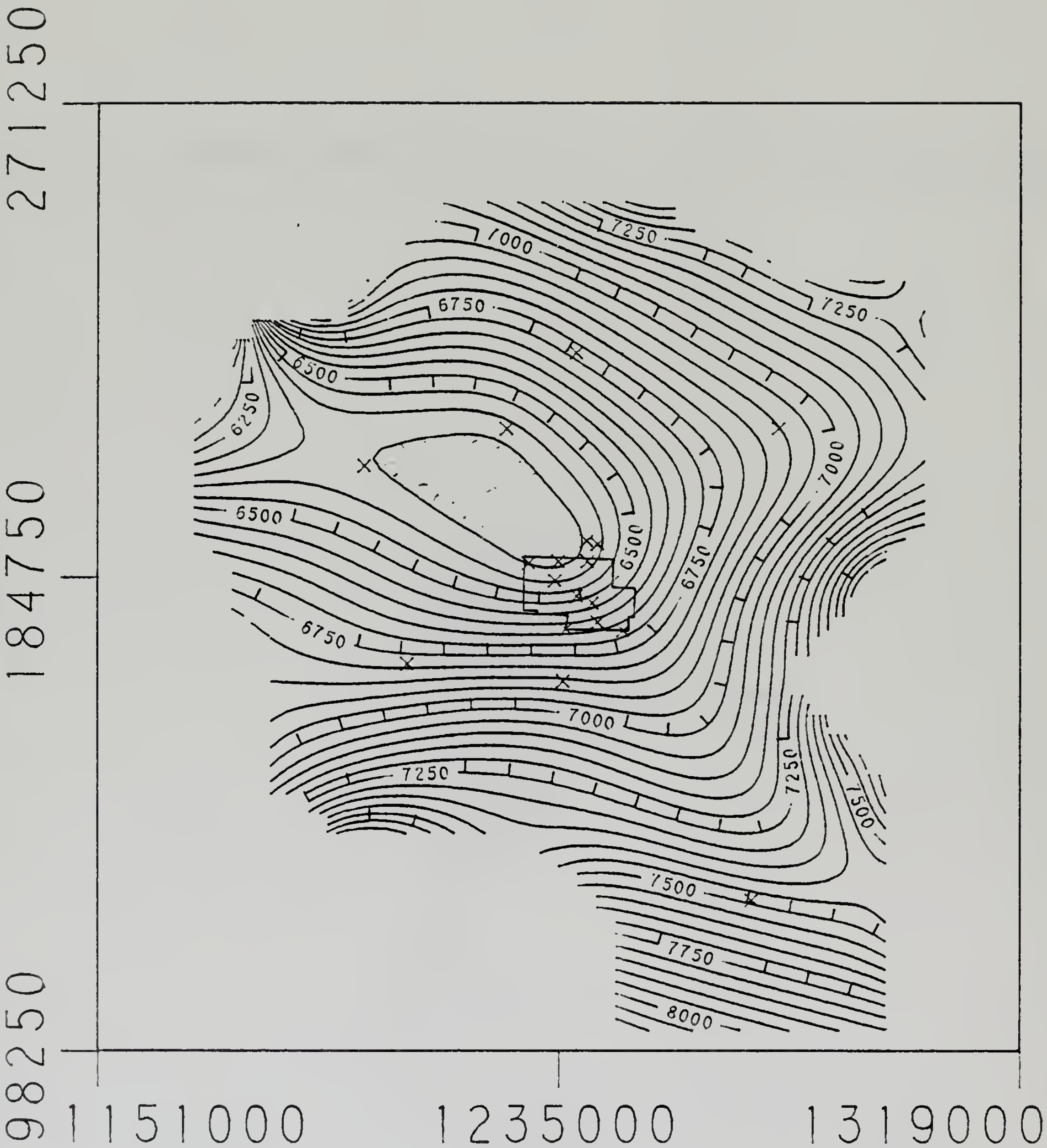


Figure 5.2.4-6
Potentiometric Surface for
Upper Aquifer Wells
September, 1980

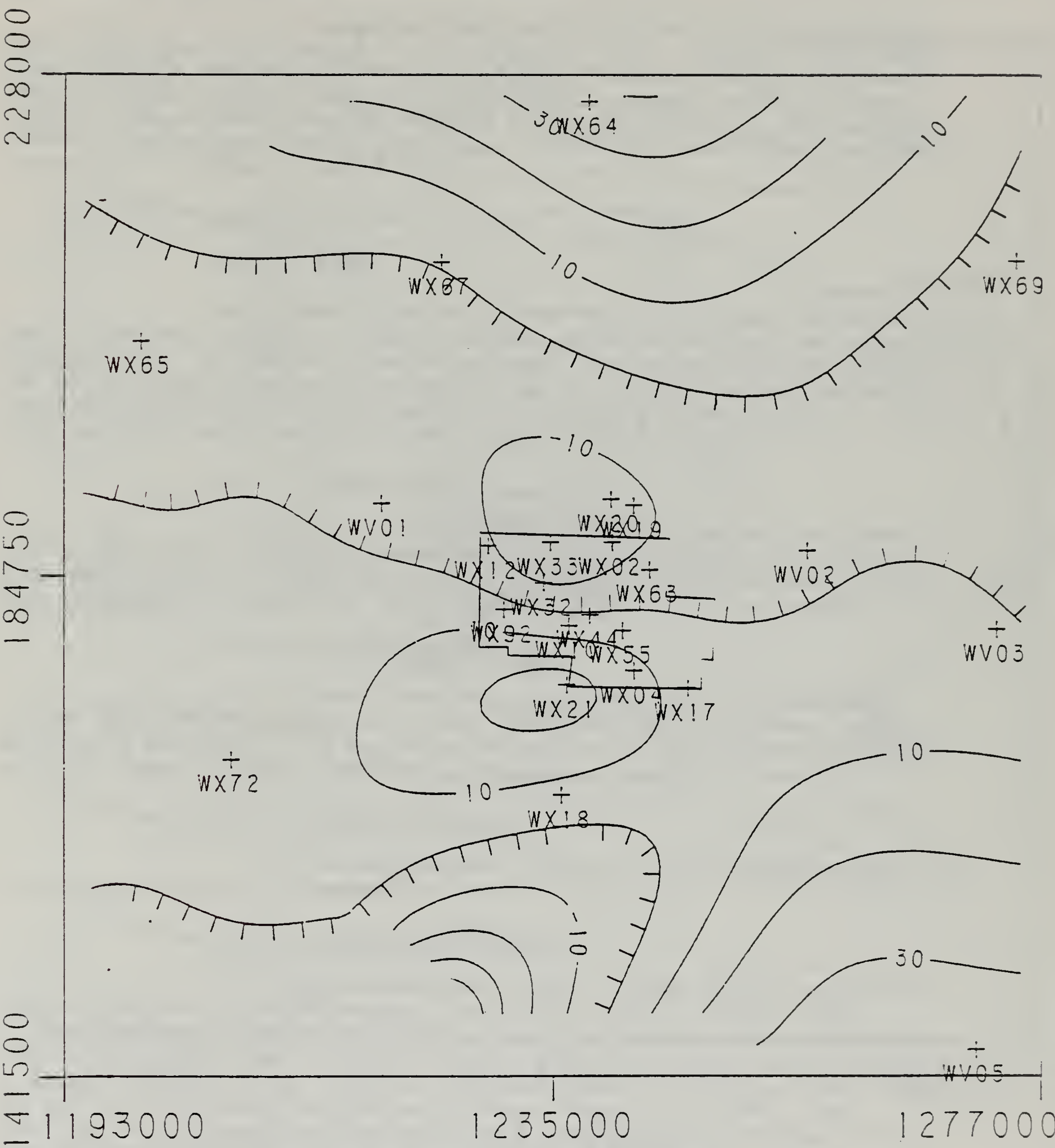


Figure 5.2.4-7
Change in Upper Aquifer
Water Levels between Baseline
and October, 1979

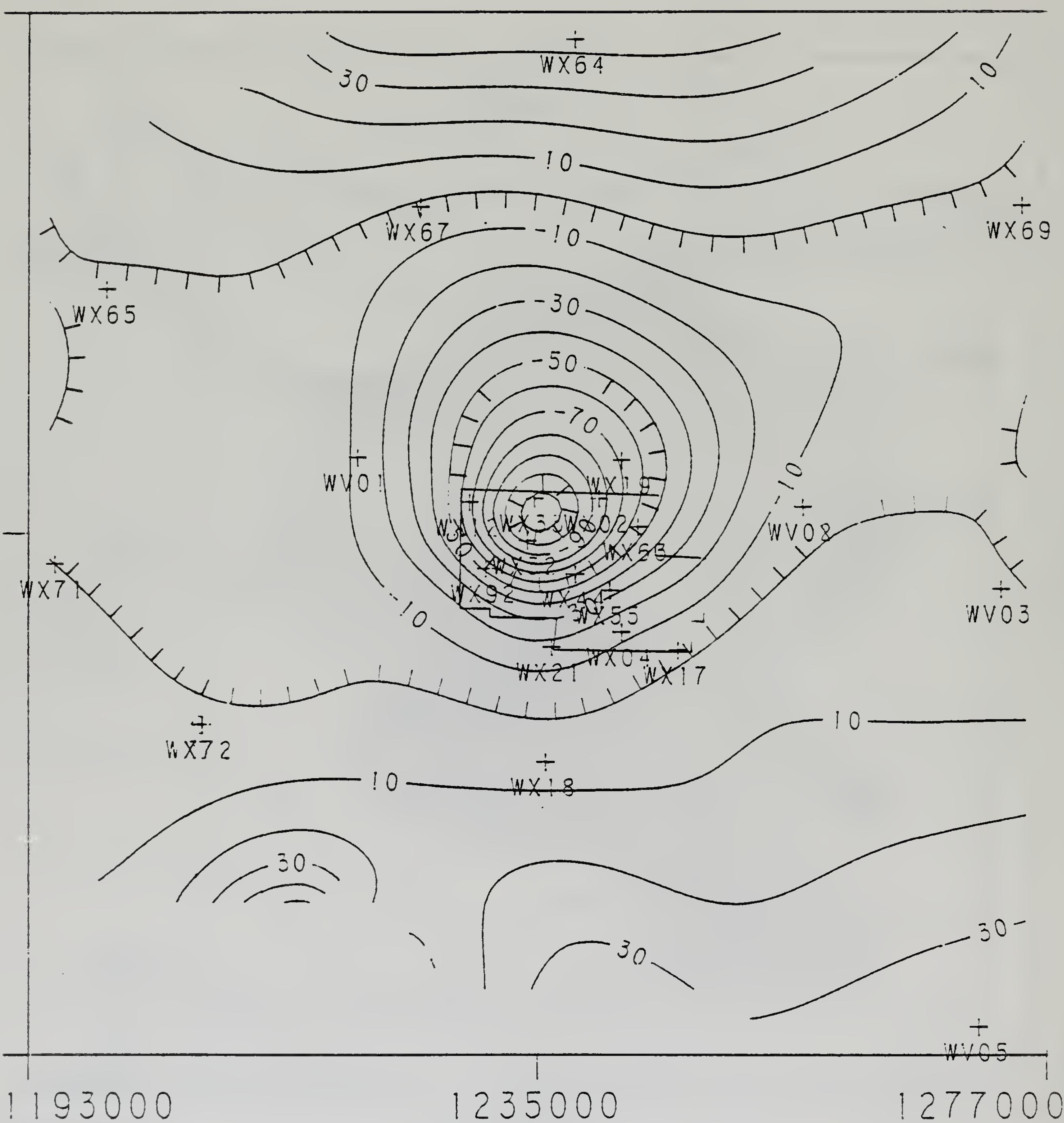


Figure 5.2.4-8
Change in Upper Aquifer Water Levels between Baseline and September, 1980

baseline and September 1980. The changes in water levels between October 1979 and September 1980 are shown in Figure 5.2.4-9.

Long-term Upper Aquifer data were also analyzed for time trends by using a general linear regression model. Results of the linear trends analysis are shown in Table 5.2.4-4. On-Tract wells with significant negative trends are WX17, WX32, WX33, WX44, WX63, and WX92. Off-Tract wells which show significant long-term negative trends are WX14, WX17, WX19 and WX20. Trends in water levels for all other Upper Aquifer wells were either positive or do not exist as shown in Table 5.2.4-4.

5.2.5 Lower Aquifer Wells

5.2.5.1 Scope

The original notation of Upper Aquifer and Lower Aquifer was made to simplify a complex system of aquifers and aquitards above and below the Mahogany Zone. The monitoring network of wells has been modified with deletions and additions and by recompleting baseline wells. The well network monitoring the Lower Aquifer was shown previously on Figure 5.2.4-1 and 5.2.4-2. A list of these wells and their sampling schedule may be found in Figure 5.2.5-1.

5.2.5.2 Objectives

As in Section 5.2.4.2 for the Upper Aquifer, Lower Aquifer water levels are monitored to ascertain if the quantity of water in the Lower Aquifer will be affected by Project development activities and to ascertain the effects of dewatering during shaft sinking and mine development.

5.2.5.3 Experimental Design

Water levels are sampled monthly at the 13 Lower Aquifer wells network established by the Development Monitoring Plan. A network of 14 wells was added to the monitoring network by the Water Augmentation Plan and Court Decree (W3492). These wells are sampled monthly.

5.2.5.4 Method of Analysis

The methods used to analyze the data were the same as for the data required for the Upper Aquifer Section 5.2.4.4.

5.2.5.5 Discussion and Results

Short-term water levels in Lower Aquifer wells were shown to increase in only four wells: WY70, WY72, WY75, and WY78 (Table 5.2.5-2). No short-term trends could be identified in wells WY03, WY10, WY52, WY66, WY76, or WY79 (Table 5.2.5-3). In all other wells water levels declined as shown in Table 5.2.5-2. Large declines were shown in wells near the shafts; the decline in all other on-Tract wells ranged from 20 to 45 feet. The off-Tract wells showed small changes in water levels with the declines of four feet or less. The maximum rise in water level was eight feet.

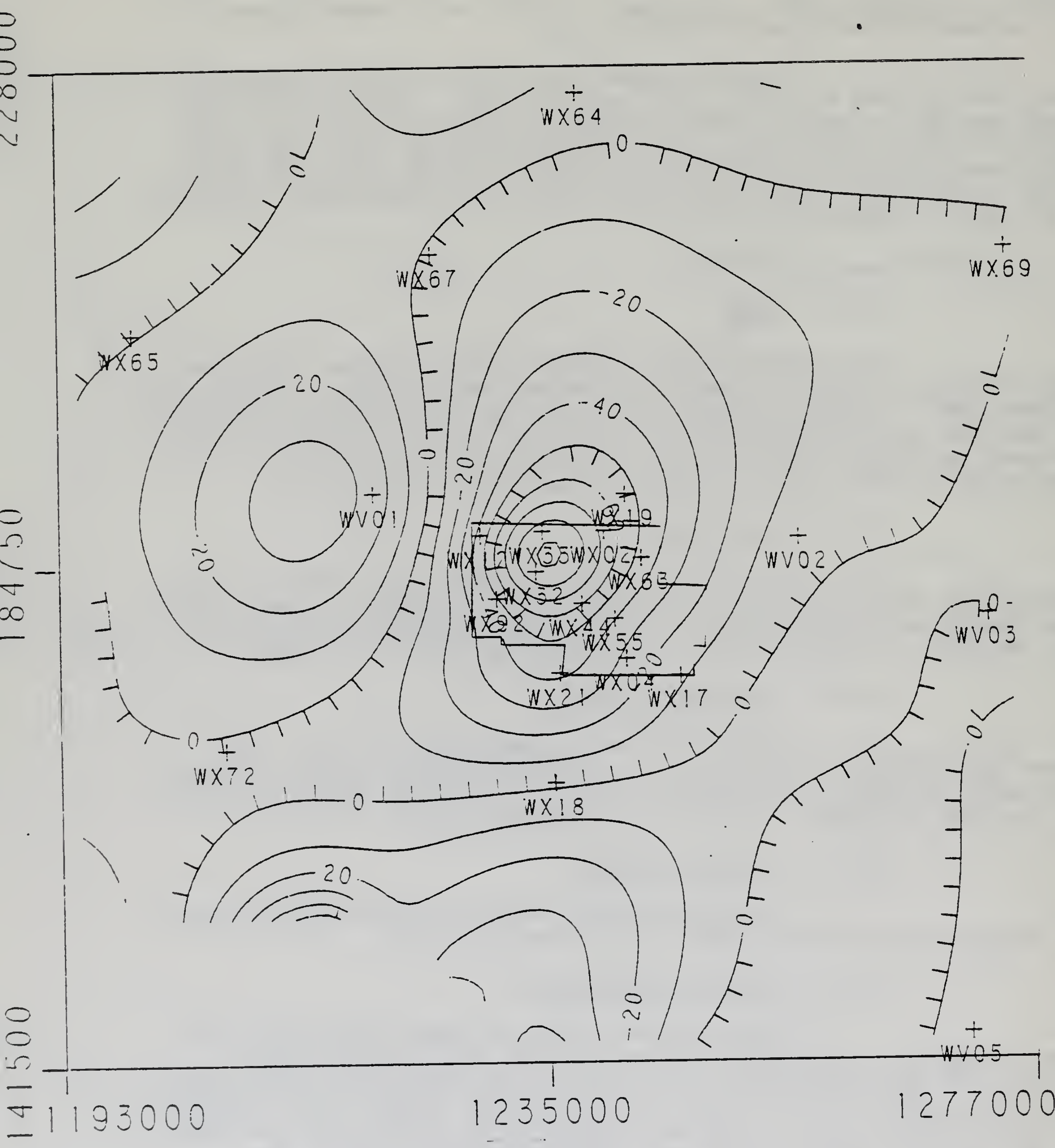


Figure 5.2.4-9
Changes in Upper Aquifer
Water Levels between
October, 1979 and
September, 1980.

TABLE 5.2.4-4

LONG TERM TIME SERIES ANALYSIS FOR DEPTH OF UPPER AQUIFER WELLS

	WX02	WX04	WX10	WX11	WX12	WX14	WX17
1.	6396.7324/61	6623.4189/56	6576.4996/38	6201.3248/7	6361.6736/57	-408.5949/2*	6639.3260/52
2.	0.0001	0.6576	0.2560	0.0097	0.0001	0.0000	0.0037
3.	-0.0271			-1.9070	-0.0097	-0.1113	-0.0017
4.	6571.8341			19807.1810	6424.9494	429.7989	6650.5867
5.	0.5858			0.7678	0.5061	1.0000	0.1566

	WX18	WX19	WX20	WX21	WX32	WX33	WX41
1.	6898.6222/42	6365.3897/44	6319.0240/14	6709.5279/54	6417.7883/31	6337.1026/31	6437.8477/2*
2.	0.0047	0.0001	0.0001	0.3299	0.0001	0.0001	0.0000
3.	0.0016	-0.0263	-0.2405		-0.2477	-0.2021	0.0198
4.	6888.2768	6541.4871	8081.8156		8143.5572	7745.0271	6293.6884
5.	0.1835	0.57059	0.94030		0.6566	0.81629	1.0000

	WX44	WX55	WX63	WX64	WX65	WX67	WX69
1.	6535.2460/41	6551.7090/47	6550.3883/58	6760.4685/13	6332.8831/13	6308.7142/13	6896.8675/13
2.	0.0001	0.0001	0.0001	0.0001	0.0131	0.1555	0.1034
3.	-0.0215	0.0055	-0.0170	0.0142	0.0039		
4.	6674.8846	6516.0532	6661.8023	6656.0266	6304.2729		
5.	0.3841	0.5320		0.9828	0.4426		

	WX72	WX73	WX75	WX82	WX92
1.	6760.0676/13	7649.1058/13	7516.1435/11	6451.2523/5	6520.1742/51
2.	0.0428	0.2807	0.3512	0.9351	0.7550
3.	0.0052				
4.	6721.6186				
5.	0.3229				

NOTE: Entries in the table mean the following:
1. Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α. ($\alpha = 0.05$)
3. Slope - slope is units per month
4. Intercept
5. r^2 value

* Linear regression modeling with two observations will produce an α=0.0000 and an r^2 value of 1. No conclusions should be made in this case.

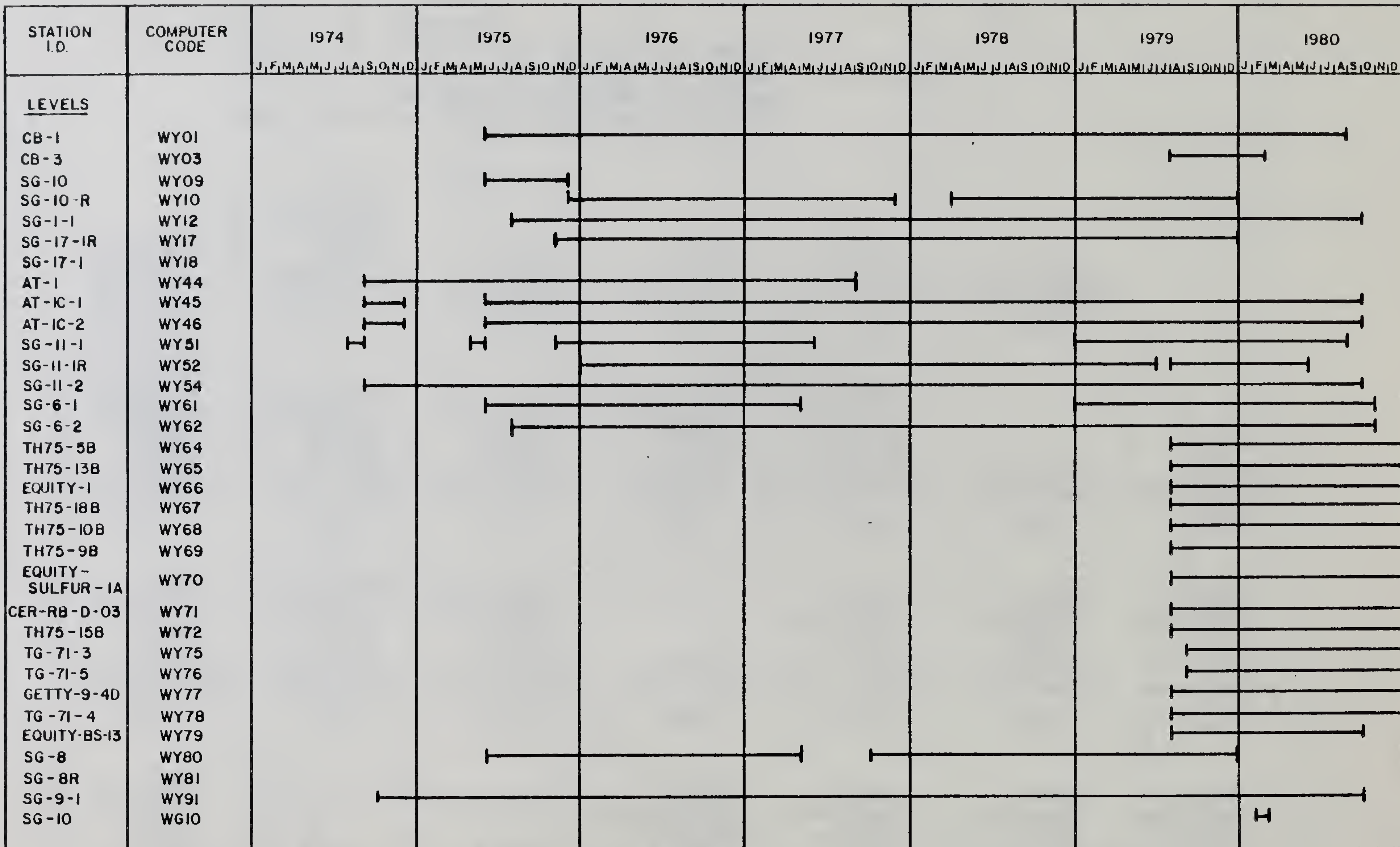


FIGURE 5.2.5-1
LOWER TRACT AQUIFER WELLS
SAMPLING TIME INTERVALS
FOR LEVELS

TABLE 5.2.5-2

Lower Aquifer Monitoring Network

Mid-Year Water Levels & Changes

Short Term Data 1980 Water Year

Well	Approximate Mid-Year Elevation (ft)	Direction of Change	Approximate Change (ft)
WY01	6,480	Decrease	-115
WY03	6,370	Decrease	-35
WY10	Scarce Data		
WY12	6,345	Decrease	-25
WY17	6,645	Decrease	-20
WY45	6,490	Decrease	-45
WY46	6,490	Decrease	-60
WY52	6,522	Slight Decrease	-2
WY54	6,543	Small Decrease	-7
WY61	6,520	Decrease	-25
WY62	6,500	Decrease	-33
WY64	6,444	Slight Decrease	-2
WY65	6,312	Slight Decrease	-1
WY66	Scarce Data		
WY67	6,235	Slight Decrease	-1
WY68	6,509	Slight Decrease	-3
WY69	6,886	Slight Decrease	-1
WY70	6,950	Increase	+8
WY71	6,574	Slight Decrease	-1
WY72	6,775	Small Increase	+4
WY75	6,770	Slight Increase	+1
WY76	6,871	No Change	-
WY78	7,075	Small Increase	+5
WY79	Scarce Data		
WY91	6,475	Decrease	-7

TABLE 5.2.5-3

Water Level of Lower Aquifer Wells

Results of General Linear Regression

Short-Term 1980 Data

Well	Mean Water Level	n	$\hat{\alpha}$ *	Slope Feet/Mo	R^2	
WY01	6362.9	12	.0001	-0.305	0.865	Linear Trend
WY03	6375.3	4	.1542			No Linear Tread
WY10	6552.9	2				Insufficient Data
WY12	6348.2	11	.0003	-0.066	0.786	Linear Trend
WY17	6652.4	9	.0071	0.003	0.668	" "
WY45	6504.0	10	.0037	-0.130	0.671	" "
WY46	6504.2	10	.0054	-0.140	0.636	" "
WY52	6524.1	10	.3667			No Linear Trend
WY54	6534.5	10	.001	-0.078	0.902	Close Fit Linear Trend
WY61	6494.9	11	.0019	-0.086	0.675	Linear Trend
WY62	6496.6	11	.0005	-0.164	0.759	" "
WY64	6443.6	12	.0008	-0.008	0.691	" "
WY65	6312.5	12	.0035	-0.006	0.590	" "
WY66	6289.3	4	.6106			No Linear Trend
WY67	6235.3	12	.0012	-0.002	0.669	Linear Trend
WY68	6509.3	12	.0001	-0.008	0.939	Close Fit Linear Trend
WY69	6885.8	12	.0004	-0.002	0.725	Linear Trend
WY70	6950.9	8	.0015	0.030	0.834	" "
WY71	6573.9	9	.0001	-0.005	0.971	Close Fit Linear Trend
WY72	6774.7	12	.0011	0.009	0.673	Linear Trend
WY75	6770.5	12	.0032	0.003	0.600	" "
WY76	6871.1	4	.2968			No Linear Trend
WY78	7076.9	12	.0029	0.015	0.604	Linear Trend
WY79	6675.0	1				Insufficient Data
WY91	6475.3	10	.0001	-0.164	0.888	Linear Trend

* $\hat{\alpha}$ less than 0.05 implies a significant linear trend.

A general linear regression model was used on the water level data obtained from some of the wells during 1980. The results of the regression with respect to time are presented in Table 5.2.5-3. The linear model fit most of the data, but the R^2 values vary widely and the linear model should be considered only as an initial screening technique. The highest R^2 for linear correlation on-Tract was 0.902 at WY54 (SG11 string 2). The model shows a decline of 0.078 feet per month. Two off-Tract water augmentation monitoring wells, WY68 and WY71 have R^2 values of 0.939 and 0.971 and would have the closest fit by the linear model over time. Both models have a slightly declining slope which is considered insignificant.

Long-term data from Lower Aquifer wells were analyzed for linear trends with time. Results of this analysis are summarized in Table 5.2.5-4. Long-term data show positive linear trends in wells WY10, WY17, WY44, WY52, WY70, WY72, WY75, and WY78. No long-term trends have been established in WY54, WY61, WY64, WY66, WY69, WY80, or WY81. Water levels in all other Lower Aquifer wells showed negative linear trends with time.

Most of the off-Tract monitoring wells showed some decline in lower aquifier water levels, but the levels of decline are less than four feet. If these declines were related to dewatering activities on the Tract, then the following would be observed in off-Tract wells:

1. The rate of decline should increase as the rate of dewatering is increased. If there is no increase in the rate of dewatering, the rate of decline would not increase unless the cone of influence reaches a hydrologic boundary.
2. Declines should occur in decreasing amounts with distance from the tract in any given direction. Local observations from a smooth inverse relationship may occur.
3. There should be less decline in Lower Aquifer wells than in the Upper Aquifer wells.

Plots of water level with time were made for all lower aquifer wells and are presented in the Appendix. None of the off-Tract wells exhibited an increased rate of decline as dewatering progressed. A time lag might be expected at remote distance from the drawdown site, however, the response is usually quite rapid in confined aquifer systems.

The declines in the lower aquifer wells do not occur in decreasing amounts with distance from the Tract; for example, the decline at WY68 is two and one-half feet; eight miles north, the decline in WY64 was four feet. Other examples can be seen on the accompanying tables. No decline has occurred in WV01, a composite well 2.5 miles northwest of the tract, and yet WY65 2.5 miles further northwest had two feet of decline. The examples cited here are evidence that declines in the levels in the Lower Aquifer wells off-Tract are not related to activities on the C-b Tract.

Composite wells (the WV series) are all located off-Tract. These five wells are completed in both the upper and lower aquifers. Plots of water levels with time are shown in Figure 5.2.5-2. The variations in the behavior of these wells and their locations with respect to the Tract

TABLE 5.2.5-4

LONG TERM TIME SERIES ANALYSIS FOR DEPTH IN LOWER AQUIFER WELLS

	WY01	WY03	WY09	WY10	WY12	WY17	WY44
1.	6395.5850/61	6408.0256/18	6497.5326/6	6539.9023/27	6355.0753/52	6640.7970/45	6523.6734/20
2.	0.0001	0.0001	0.0201	0.0246	0.0001	0.0001	0.0001
3.	-0.0311	-0.0321	-0.3504	0.0039	-0.0093	0.0166	0.0508
4.	6600.6074	6608.1869	8496.8097	6515.3049	6416.3935	6531.2341	6217.9261
5.	0.2949	0.7482	0.7776	0.1862	0.6611	0.9386	0.7453

	WY45	WY46	WY52	WY54	WY61	WY62	WY64
1.	6513.8656/57	6514.3409/43	6511.7991/48	6539.2447/45	6492.7979/43	6508.9246/60	6442.0222/13
2.	0.0024	0.0045	0.0001	0.6537	0.5415	0.0001	0.1904
3.	-0.0062	-0.0070	0.7567			-0.0152	
4.	6553.8910	6559.5989	6511.7991			6609.2021	
5.	0.1550	0.1807	0.7567			0.2686	

	WY65	WY66	WY67	WY68	WY69	WY70	WY71
1.	6312.6061/13	6282.6729/4	6235.3600/13	6509.3984/13	6897.5292/13	6950.9111/8	6573.8655/9
2.	0.0021	0.6428	0.0004	0.0001	0.0675	0.0015	0.0001
3.	-0.0051		-0.0015	-0.0078		0.0301	-0.0056
4.	6350.4913		6426.4221	6567.1043		6726.8061	6615.7694
5.	0.5935		0.6933	0.9489		0.8336	0.9709

	WY72	WY75	WY76	WY78	WY80	WY81	WY91
1.	6774.6370/13	6770.4291/13	6858.9063/4	7076.6295/13	6451.2188/5	6525.9586/5	6498.4741/48
2.	0.0007	0.0009	0.3202	0.0004	0.8748	0.6792	0.0001
3.	0.0077	0.0036	-0.0012	0.0154			-0.0191
4.	6717.8965	6743.9222	6868.0106	6963.0437			6623.7129
5.	0.6593	0.6503	0.4622	0.6897			0.6232

NOTE: Entries in the table mean the following:
1. Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α. (α = 0.05)
3. Slope - slope is units per month
4. Intercept
5. r^2 value

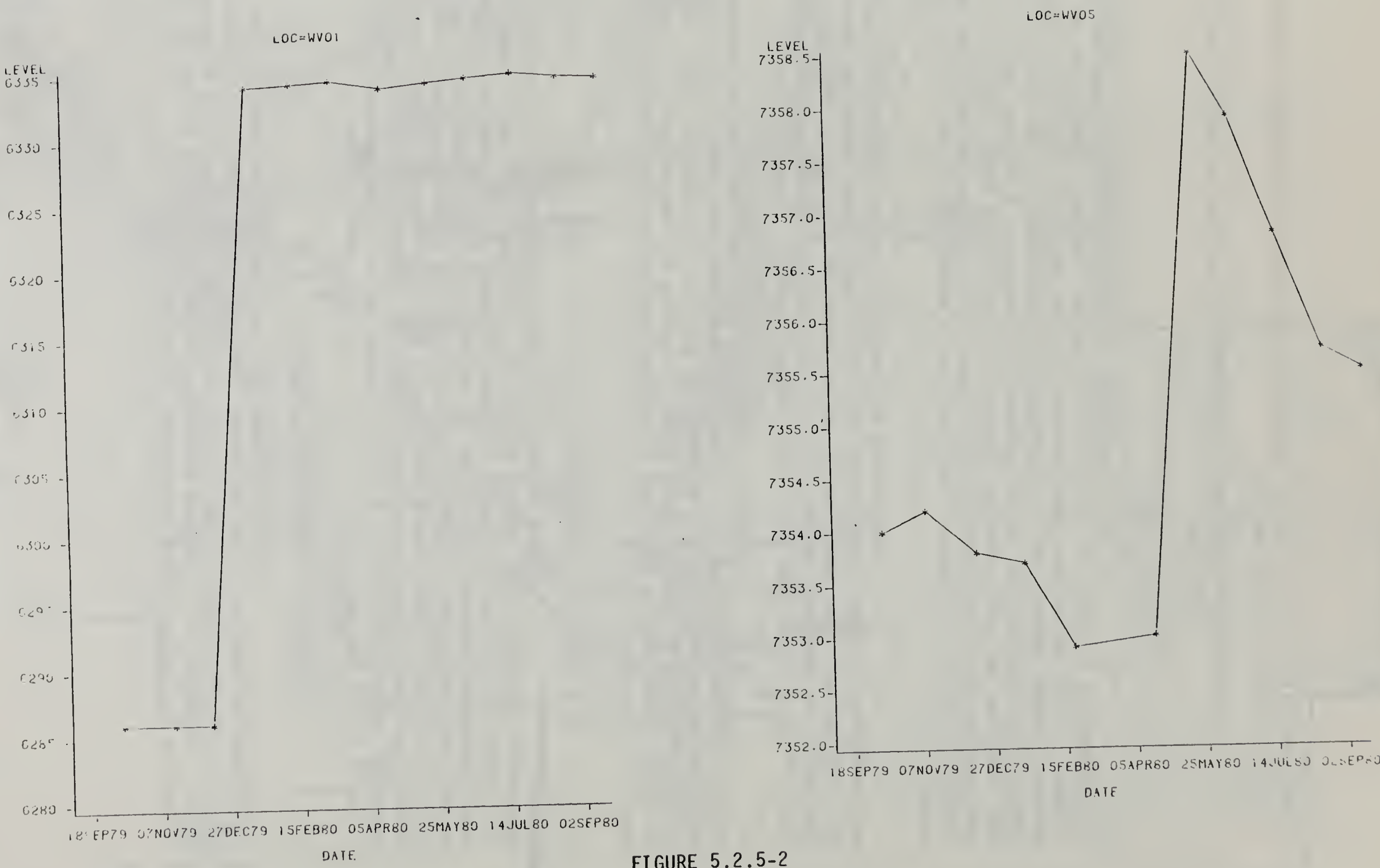


FIGURE 5.2.5-2
Composite Well Levels

eliminate Project activities as responsible for any of the changes in water levels monitored at these wells.

5.2.6 Water Management: Impoundments/Land Application/Reinjection/ Discharge

5.2.6.1 Scope

Water management is defined herein as management of water produced on Tract in excess of daily needs. Various alternatives to management of this water have been proposed and the management techniques that are presently being implemented include temporary impoundments, land application through the sprinkler irrigation system, or discharge. A reinjection test well was installed but works were not completed by the end of 1980. Figure 5.2.6-1 presents the water management system, Figure 5.2.6-2 shows the sprinkler system. Figure 5.2.6-3 is a diagram of holding Ponds A and B, and Figure 5.2.6-4 shows Pond C.

Water from the ponds was either discharged or sprinkled, depending on quantity, quality, and time of year. When water was discharged, flow was monitored specifically at surface water gauging station WU42 in No Name Gulch and at WU45, the new station constructed 50 meters downstream from the confluence of No Name Gulch and Piceance Creek.

Quantities of water were produced from groundwater through the dewatering process. Although water flow into shafts and related works was minimized as much as possible by grouting and concrete shaft liners, it was necessary to dewater shaft works by pumping to the surface in a series of lifts. This surplus water was eliminated through the water management system.

5.2.6.2 Objectives

The objective in water management is to dispose of excess water generated from various activities, principally the water pumped from the shafts and related workings. Treatment of water quality for the present water management system is discussed in detail in 5.3. The quantity of water routed into the temporary storage facilities and the quantity removed from storage by discharge or other means must comply with requirements of the Tract NPDES Permit, the State Subsurface Disposal Permit for reinjection of mine water, and the Water Augmentation Plan. A table of water use on Tract in 1980 is presented on Table 4-4 of Volume 1.

5.2.6.3 Experimental Design

Waters pumped into the ponds and discharged from Pond B into East No Name Gulch are measured. The NPDES Permit limits discharge volume with specific permit criteria based on water quality impacts to Piceance Creek. The design is to compare discharge volumes from Pond B to that of total streamflow in Piceance Creek downstream of the discharge point.

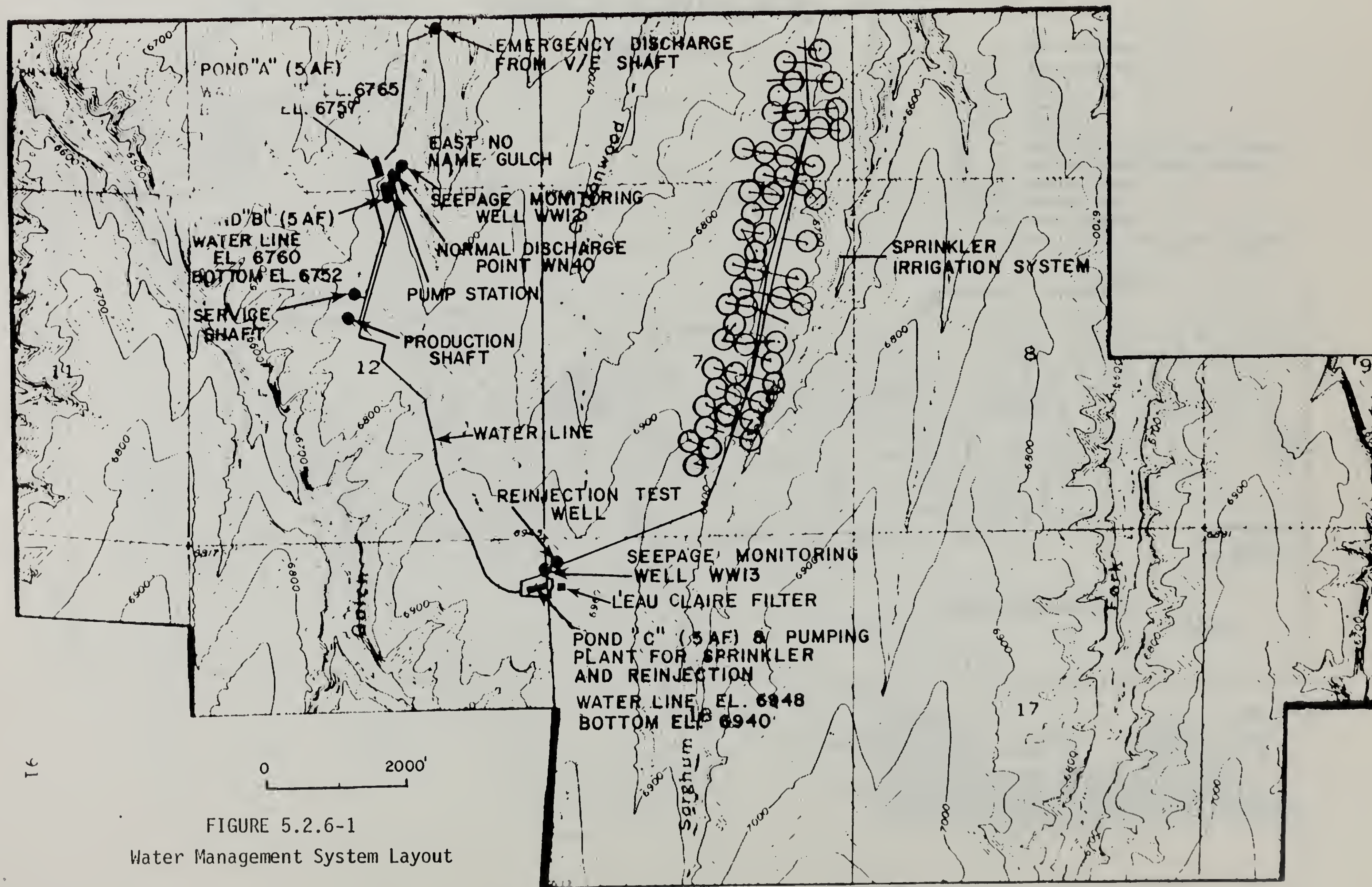


FIGURE 5.2.6-1
Water Management System Layout

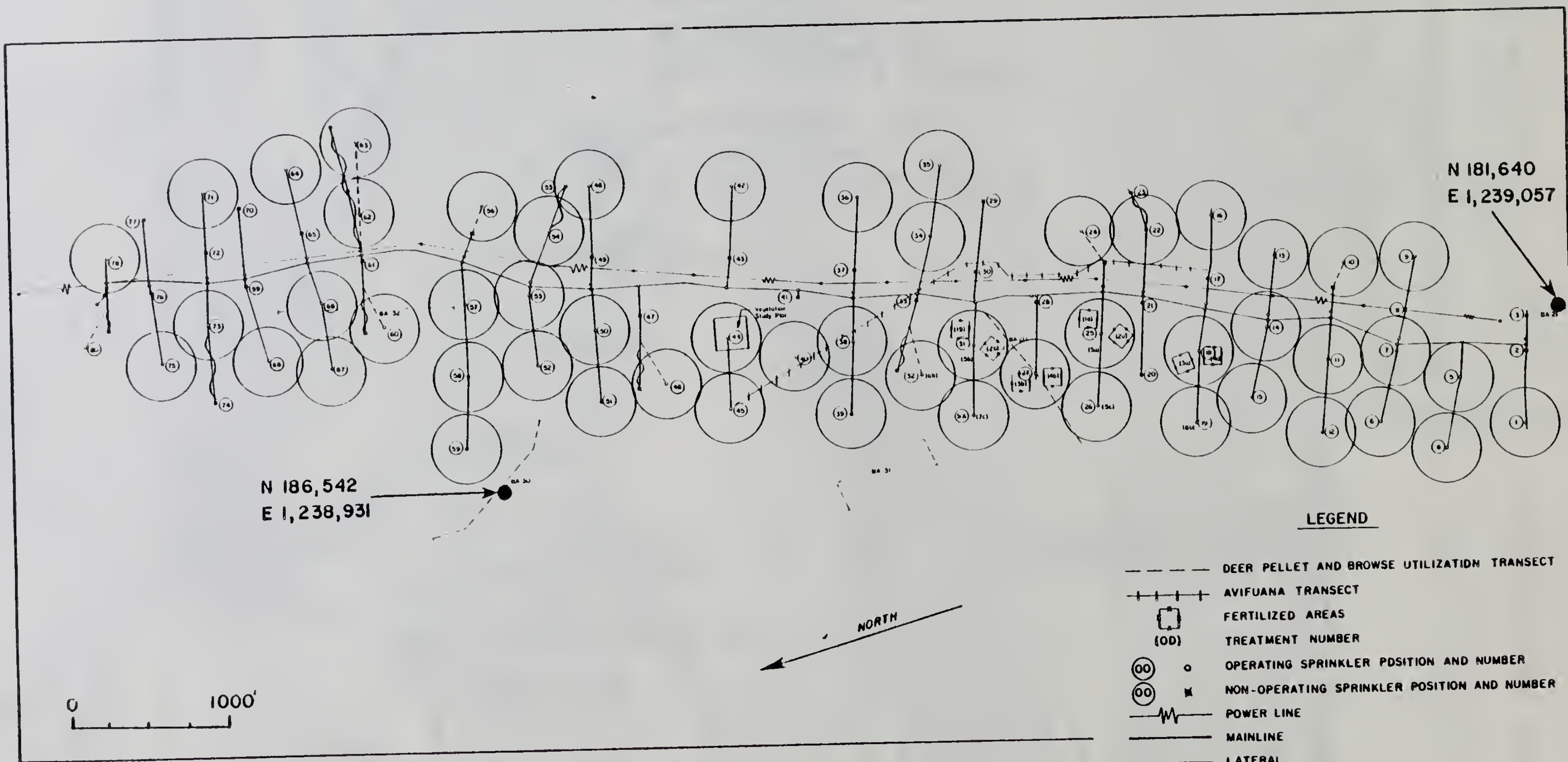


FIGURE 5.2.6-2

SPRINKLER IRRIGATION PLAN

FIGURE 5.2.6-3

LOWER 5 ACRE—FOOT MINE WATER HOLDING PONDS; C—b TRACT

SCALE 1"=106.67'

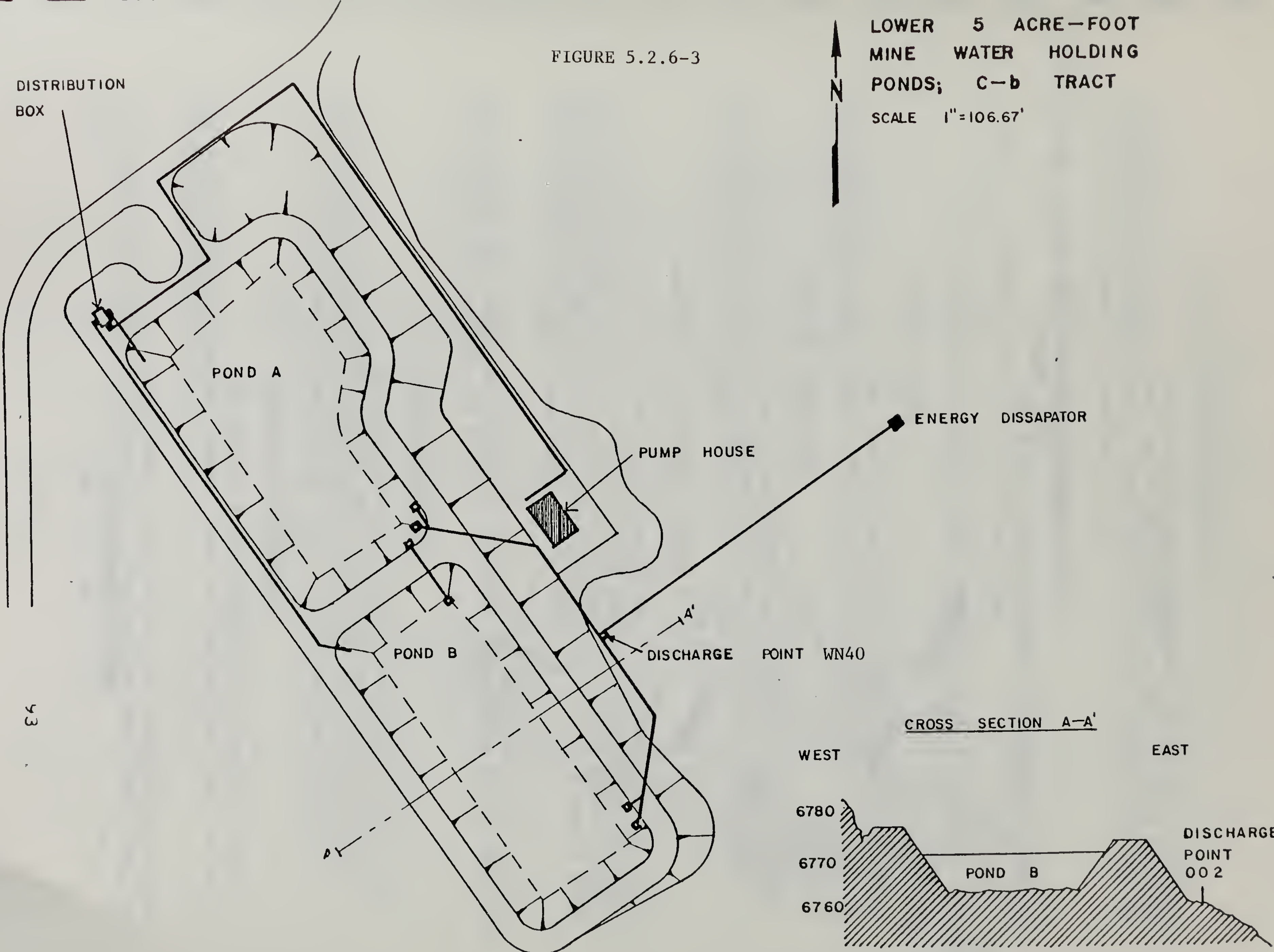
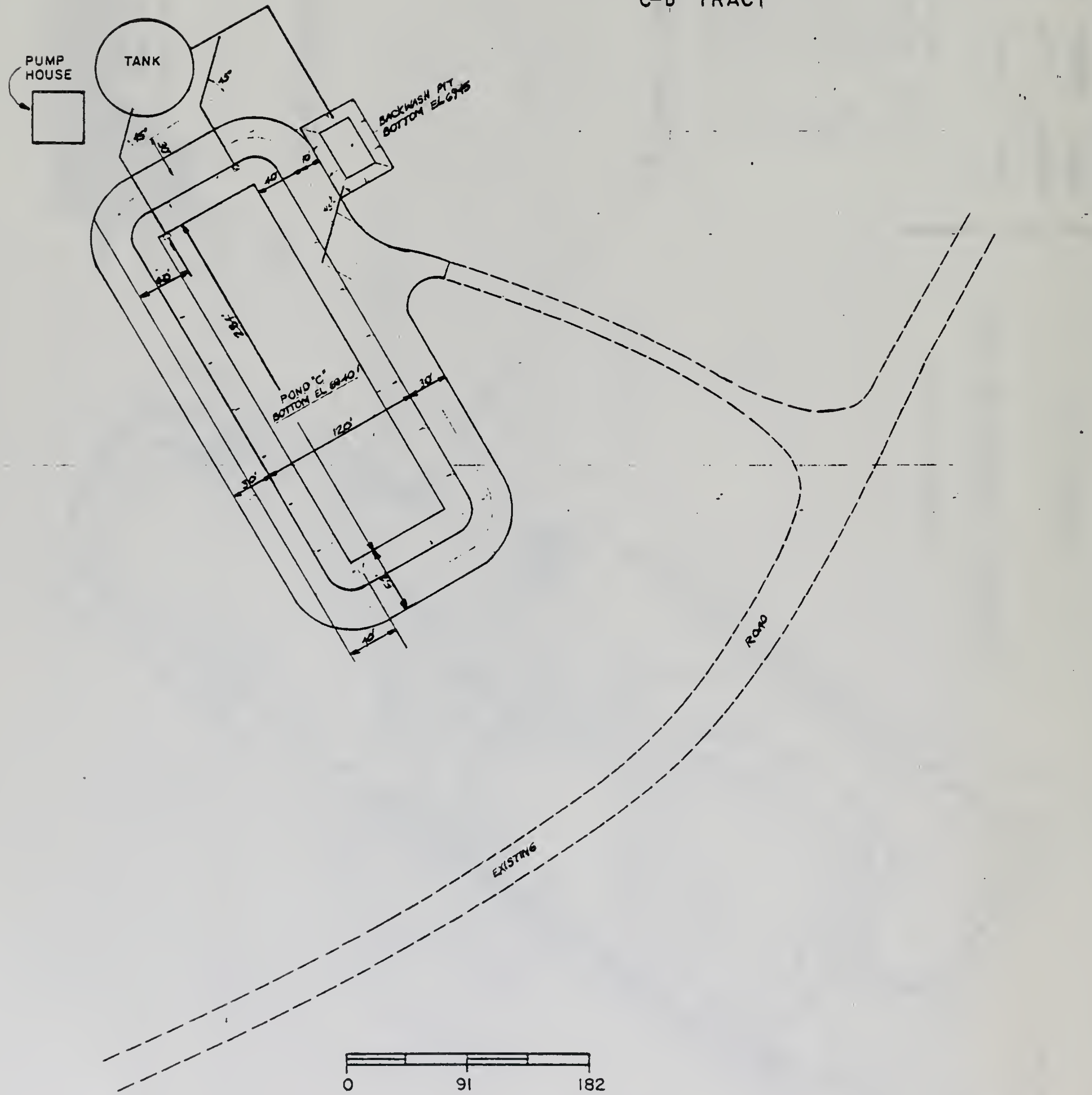


FIGURE 5.2.6-4

UPPER 5 ACRE-FOOT MINE WATER HOLDING POND
C-b TRACT



5.2.6.4 Method of Analysis

Data from the water management system were analyzed by inspection of tabulated values and ratios of flows from WN40 (Pond B) and WU61 (Piceance Creek at Hunter Creek). More detailed analysis methods were applied to water quality data as discussed in 5.3.6.

5.2.6.5 Discussion and Results

Table 5.2.6-1 shows the NPDES discharges at WN40, the discharge past WU61, and the ratio of these flows.

5.2.7 Correlations Suggested Under the Water Augmentation Plan

5.2.7.1 Scope

Some specific correlations were suggested under the Water Augmentation Plan. These correlations are discussed here.

5.2.7.2 Objectives

To perform corrrelations of flow in Piceance Creek with precipitation occurring at various flow and preciptiation measurement in the Tract area and with the Little Hills Station.

5.2.7.3 Experimental Design

Primarily because of their relatively long periods of record (since October, 1964), the winter-time flow on Piceance Creek at Ryan Gulch (Station WU00) and the precipitation at the Little Hills Station (WR01) were suggested as possible items to correlate with the flows on Piceance Creek upstream (WU07) and downstream (WU61) of the Tract.

Also singled out under the Water Augmentation Plan were springs WS09, WS10, and WS31 where discharge time history must be monitored and compared with that of well WX12.

5.2.7.4 Method of Analysis

In addition to correlations suggested above, these additional ones were judged to be of merit: correlation of precipitation at Stations AB20 or AB23 with Piceance Creek winter-time flows at either Ryan Gulch, the downstream station from the Tract, or the upstream station.

5.2.7.5 Discussion and Results

The monthly precipitation at Stations AB20, AB23, and Little Hills and flows on Piceance Creek at Stations WU00, WU61, and WY07 are tabulated on Table A5.2.7-1.

Histograms of winter-time flow average over December and January are presented on Figure 5.2.7-1 for Stations WU00, WU07, WU22, and WU61.

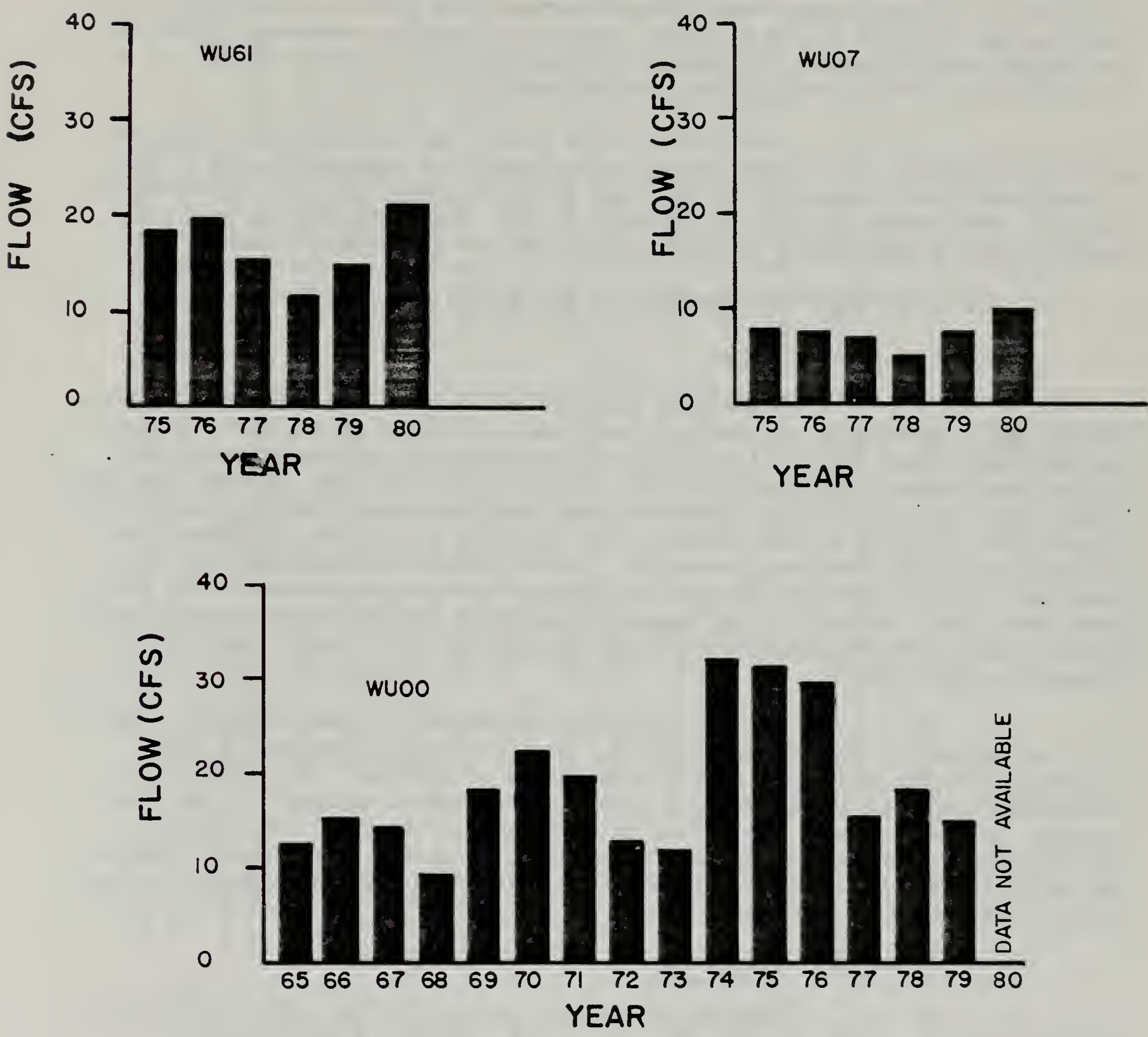
TABLE 5.2.6-1

Comparison of Discharges from Pond B (WN40) and Piceance Creek Flow at Hunter Creek(WU61)

Date	Discharge WN40 (cfs)	Discharge WU61 (cfs)	$\frac{WN40}{WU61} \times 100$
10/01/79	0.47	10.0	4.7
10/08	0.47	13.0	3.6
10/17	1.30	13.0	10.0
10/26	0.70	21.0	3.3
10/30	1.60	21.0	7.6
11/05	1.38	18.0	7.7
11/08	1.60	19.0	8.4
11/13	1.83	19.0	9.6
11/21	2.21	23.0	9.6
11/24	1.74	21.0	8.3
11/28	1.98	21.0	9.4
11/30	1.96	21.0	9.3
12/07	2.05	19.0	10.8
12/14	0.56	22.0	2.6
12/18	0.78	24.0	3.3
12/19	0.71	25.0	2.8
12/26	0.94	25.0	3.8
1/07/80	0.31	17.0	1.8
1/02	2.21	20.0	11.1
1/10	1.55	18.0	8.6
1/18	0.61	19.0	3.2
1/24	0.29	19.0	1.5
1/31	0.62	18.0	3.4
2/08	2.05	18.0	11.4
2/21	0	26.0	0
2/24	0	23.0	0
2/29	0.62	27.0	2.3
2/15	0.39	20.0	2.0
3/12	0	21.0	0
3/13	0	22.0	0
3/21	0	22.0	0
3/26	0	22.0	0
4/04	1.15	22.0	5.2
4/09	0	23.0	0
4/17	0	27.0	0
4/24	0	60.0	0
4/28	0	65.0	0
4/02	1.08	78.0	1.4
5/14	0	110.0	0
5/29	0	54.0	0
6/07	1.14	18.0	6.3
6/11	0.72	17.0	4.2
6/18	0.33	11.0	3.0
6/24	0.30	8.6	3.5
7/07	0	9.3	0
7/16	0	12.0	0
7/23	0	12.0	0
8/03	1.02	28.6	3.6
8/13	0	27.1	0
8/20	0	26.6	0
8/27	0	26.6	0
9/08	1.37	25.5	5.4
9/10	0	25.0	0
9/17	0	19.2	0
9/25	0	7.9	0

FIGURE 5.2.7-1

HISTOGRAMS OF WINTERTIME MEAN FLOW* FOR SELECTED USGS GAUGING STATIONS ON PICEANCE CREEK



$$* \left(\frac{\text{DEC. FLOW + JAN. FLOW}}{2} \right)$$

Table 5.2.7-1 summarizes the results of the correlation analysis. As seen in the table, Little Hills (WR01) precipitation shows little correlation with Piceance Creek flow. The low correlation demonstrates that precipitation is subject to marked spatial variability, especially in rough terrain. Precipitation at Stations AB20 and AB23 shows a high correlation with flow at all three Piceance Creek flow stations. This can be attributed to the locations, since both are within three miles of Station WU07. The correlations between flow at WU00 versus flow at WU07 and WU61 are excellent and confirm that correlations increase as the distance between stations is decreased. Analyses for lagged correlation for flow versus precipitation were performed but did not produce significant increases over unlagged results.

Time histories of flows from springs WS31, WS09, and WS10 and comparison with water levels in well WX12 are shown on Figure 5.2.7-2. Although well WX12 appears to be affected by Tract operations, no consistent effects on these three springs are apparent at this time; the flow in WS31 has, however, been predominantly increasing over its short period of record.

5.2.8 Hydrogeologic Mapping of C-b Shafts

5.2.8.1 Scope

Tremendous progress was made in the sinking of shafts during 1980. Hydrologic and geologic data were collected as the oil shales of the Parachute Creek member of the Green River formation were exposed during station development. In the V/E shaft, sinking continued from the pump station at 960 feet, through the Four Senators Zone which separates the UPC_1, aquifer subunit from the UPC_2 aquifer subunit. At the base of the Four Senators Zone, the station at 1050 feet was excavated. During August and September the Ignition Level station at 1170 feet was excavated. Sinking progressed toward the Upper Void Level located in the Mahogany Zone about 25 feet below the A-Groove. Grouting continued throughout sinking during the year with covers numbered six through ten completed.

Sinking continued in the Service and Production shafts with completion of the Midshaft Station, Ignition Level, Upper Void Level, Intermediate Void Level, and partial completion of the Lower Void Level. As development began at the Lower Void Level in the Production Shaft, a northeast trending fold was mapped. This fold extended across the Lower Void Level - loading pocket opening and caused ground control problems. Additional support was installed and the station was completed. The fold was not observed in the Service Shaft side of the station.

5.2.8.2 Objectives

Mapping of the hydrogeology of the shafts is done to provide better understanding of the groundwater hydrology and subsurface geology. Information is used in water management and mine planning.

5.2.8.3 Experimental Design

Hydrologic data were obtained through grouting

TABLE 5.2.7-1 PRECIPITATION - STREAMFLOW CORRELATION SUMMARY

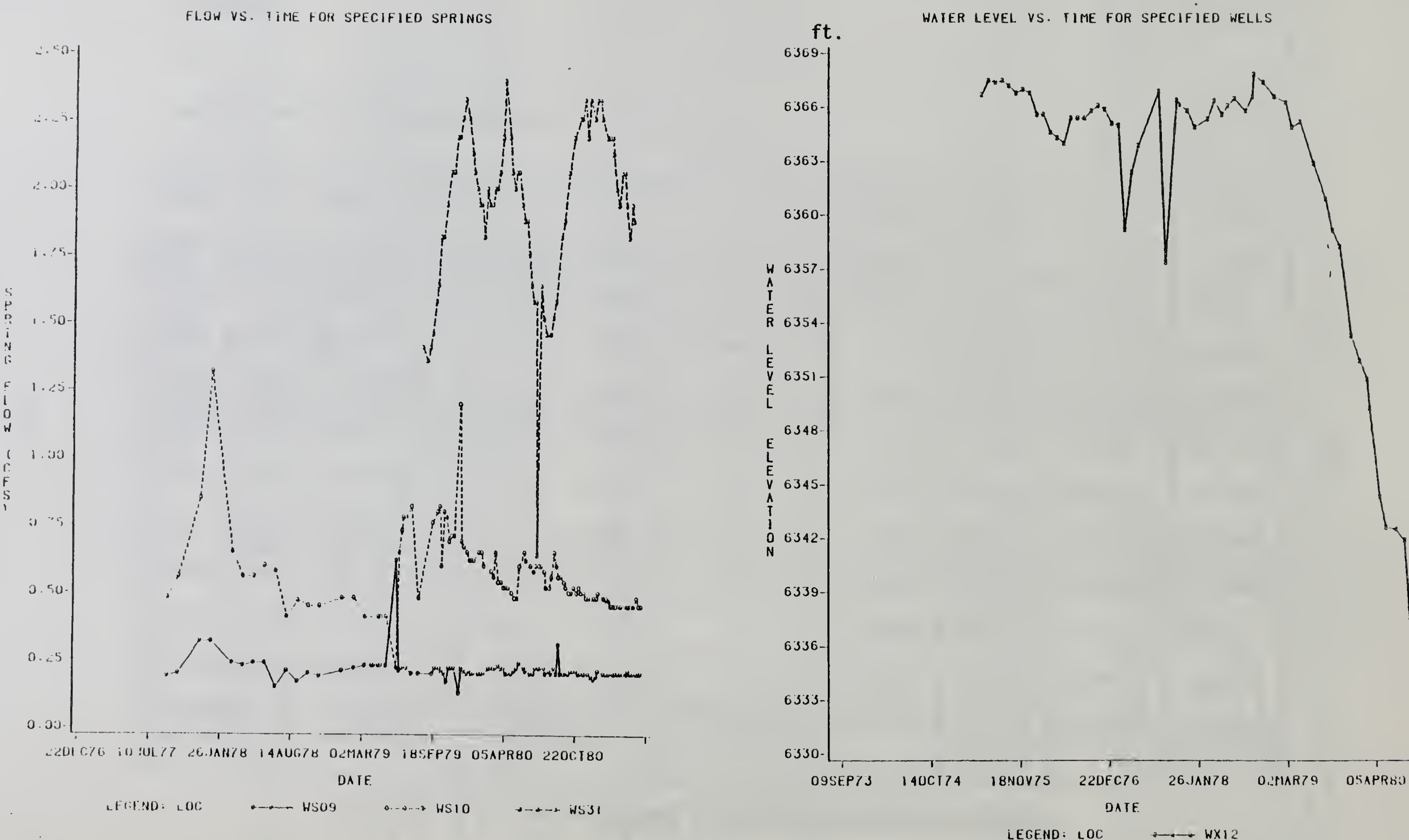
Dependent Variable	Independent Variable	Measurement Interval	No. of Observations	Pr > F	R^2	Model	
						Intercept[1]	Slope[2]
WU00 Flow	AB20 ppt	3/79 - 10/79	7	0.0293	0.65	12.20	23.02
WU00 Flow	AB23 ppt	3/79 - 10/79	7	0.0240	0.67	11.40	22.45
WU00 Flow	WR01 ppt*	3/79 - 10/79	7	0.1881	0.32	no reliable model	
WU61 Flow	AB20 ppt	3/79 - 10/80	16	0.2844	0.08	no reliable model	
WU61 Flow	AB23 ppt	3/79 - 10/80	16	0.0384	0.27	14.19	14.35
WU61 Flow	WR01 ppt	3/79 - 10/80	14	0.0306	0.33	6.39	16.75
WU07 Flow	AB20 ppt	3/79 - 10/80	16	0.4427	0.04	no reliable model	
WU07 Flow	AB23 ppt	3/79 - 10/80	16	0.0799	0.20	no reliable model	
WU07 Flow	WR01 ppt	3/79 - 10/80	14	0.0456	0.29	-0.95	19.38
WU00 Flow	WU61 Flow	3/79 - 10/79	7	0.0001	0.97	3.63	1.04
WU00 Flow	WU07 Flow	3/79 - 10/79	7	0.0002	0.95	11.33	0.88

*WR01 is the Little Hills Station

[1] cfs

[2] cfs/cm

FIGURE 5.2.7 – 2



FLOW VS. TIME FOR SPECIFIED SPRINGS
SPRING FLOW (CFS)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
22DEC76 10JUL77 26JAN78 14AUG78 02MAR79 18SEP79 05APR80 22OCT80
DATE
LEGEND: LOC WS09 WS10 WS31
WATER LEVEL VS. TIME FOR SPECIFIED WELLS
ft.
WATER LEVEL ELEVATION
6369
6366
6363
6360
6357
6354
6351
6348
6345
6342
6339
6336
6333
6330
09SEP73 14OCT74 18NOV75 22DEC76 26JAN78 02MAR79 05APR80
DATE
LEGEND: LOC WX12

activities where amounts and water quality were recorded along with total shaft inflows during sinking and physical mapping of zones that produced water. Geologic data including fracture measurements, structural data, and rock quality data were obtained in all the shafts.

5.2.8.4 Method of Analysis

Lower hemisphere stereographic plots of fracture data were constructed for the stations at 960 and 1050 feet for the V/E shaft. Each point on the plot represents a pole through a perpendicular plane and thus indicates the intersection with the lower hemisphere. Points in the center of the plot represent horizontal planes; those around the perimeter depict the vertical plane. Any dip angle may therefore be represented on the hemispheric surface. The azimuthal location of any point on the hemisphere represents the orientation or strike of the fracture. Numbers in the diagram represent the frequency of occurrence of fractures with the particular dip and strike represented by the unique point on the hemisphere. Contours are drawn for these values thus providing a visual summary of the characteristics of the fractures in the area where these measurements were made. Water inflows to the shafts were measured and tabulated.

5.2.8.5 Discussion and Results

Major fractures at 960 feet in the V/E shaft are shown on the lower hemisphere stereographic plot of Figure 5.2.8-1 and histograms of Figure 5.2.8-2. The major fractures present were oriented N71W, dipping 75 degrees SW with a minor fracture set of N72W with dips of 62 degrees NE. The combined fracture data from stations at 960 and 1050 feet are shown in the plot of Figure 5.2.8-3 and histograms of Figure 5.2.8-4. At 1050 feet fractures were oriented from N40W to N80W with dips of 53 to 55 degrees N. Many large vugs measuring three to seven feet in diameter were present. Also present in this station is a two to four feet thick core loss zone, which can be correlated around the Tract, composed of randomly oriented fractures with dips of 70 to 90 degrees. This zone is composed of blocky ground made up of pieces of oil shale from six to twelve inches across.

Fracture data from the Ignition Level at 1170 feet are shown in the Figure 5.2.8-5 stereonet and Figure 5.2.8-6 histogram. Fracture data collected showed dips from 77 to 88 degrees. The Mahogany marker bed was exposed in this station and had an elevation of 5402 feet. Fractures were not present in the Upper Void Level as were previously mapped. The rock present was massive, competent oil shale with few fractures present.

Fracture data collected in the Midshaft Level of the Service and Production shafts are shown in Figures 5.2.8-7 and the histograms in Figure 5.2.8-8. The data from the Ignition Level are shown in Figures 5.2.8-9 and 5.2.8-10. The three retort void levels were developed and, as in the V/E shaft, no major fractures were found in the Upper Void Level. The Intermediate Void Level was composed of gray siltstones and barren marlstones with few fractures present.

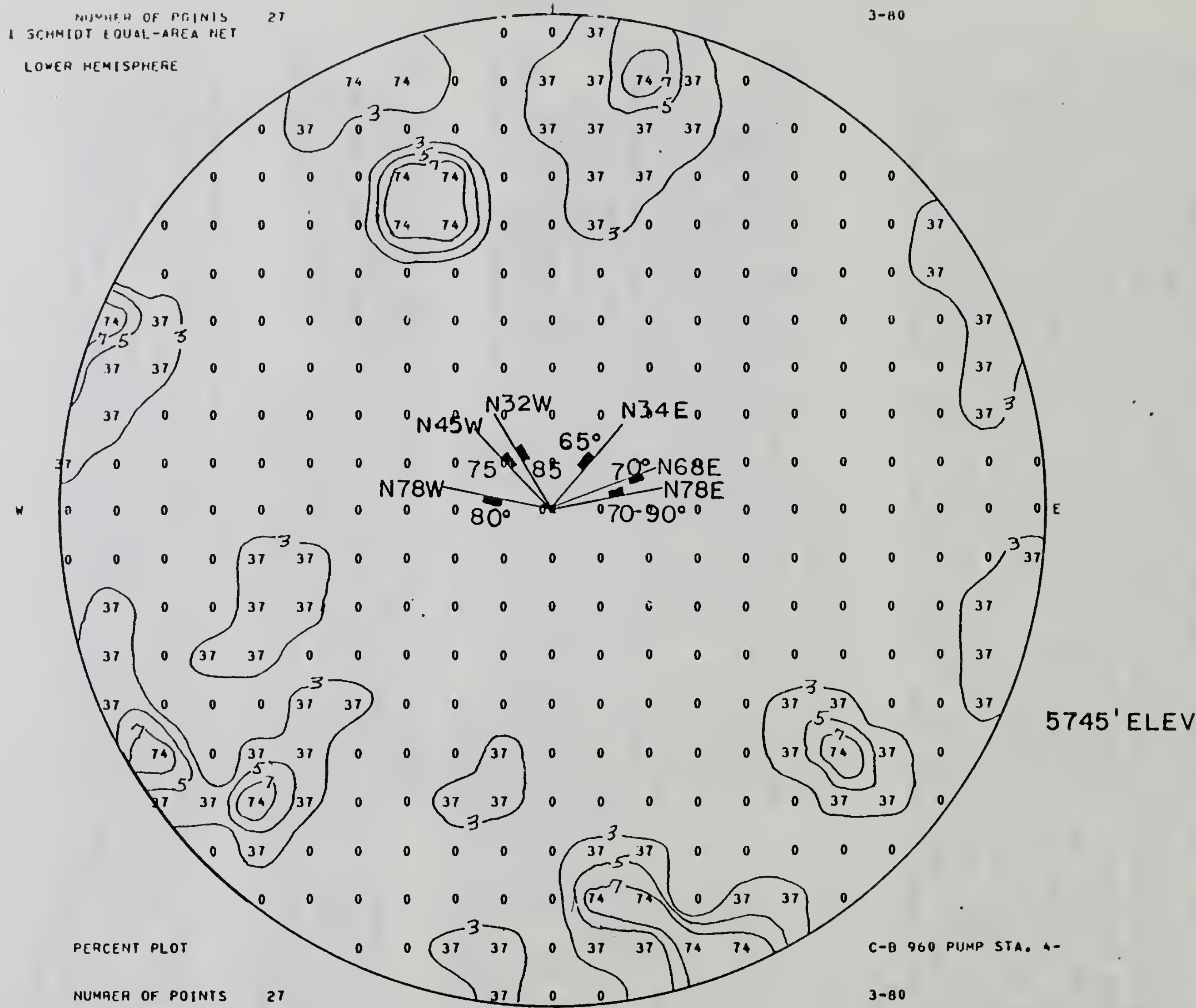


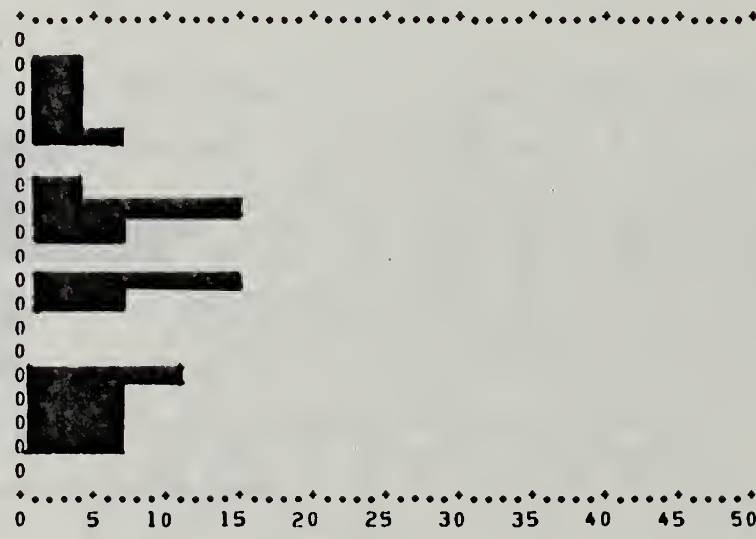
FIGURE 5.2.8-1

Stereographic Plot for C-b 960 Pump Station

	STRIKE	DIP		STRIKE	DIP		STRIKE	DIP		STRIKE	DIP		STRIKE	DIP
1	320.	53.	7	220.	75.	13	10.	90.	19	70.	60.	25	240.	86.
2	280.	50.	8	95.	74.	14	105.	86.	20	330.	90.	26	325.	86.
3	345.	90.	9	345.	46.	15	280.	83.	21	105.	72.	27	315.	75.
4	70.	60.	10	68.	90.	16	260.	66.	22	260.	78.	28	0.	0.
5	25.	79.	11	100.	57.	17	335.	90.	23	335.	60.	29	0.	0.
6	220.	62.	12	20.	90.	18	70.	90.	24	315.	70.	30	0.	0.

STRIKE HISTOGRAM

AZ	NO	PCT
0	0	0.0
10	1	3.7
20	1	7.4
30	1	11.1
40	2	18.5
50	0	18.5
60	1	22.2
70	4	37.0
80	2	44.4
90	0	44.4
100	4	59.3
110	2	66.7
120	0	66.7
130	0	66.7
140	3	77.8
150	2	85.2
160	2	92.6
170	2	100.0
180	0	100.0
TOTAL	27	



960 Pump Station

DIP HISTOGRAM

DIP	NO	PCT
0	0	0.0
5	0	0.0
10	0	0.0
15	0	0.0
20	0	0.0
25	0	0.0
30	0	0.0
35	0	0.0
40	0	0.0
45	1	3.7
50	1	7.4
55	2	14.8
60	4	29.6
65	1	33.3
70	2	40.7
75	3	51.9
80	2	59.3
85	4	74.1
90	7	100.0
TOTAL	27	

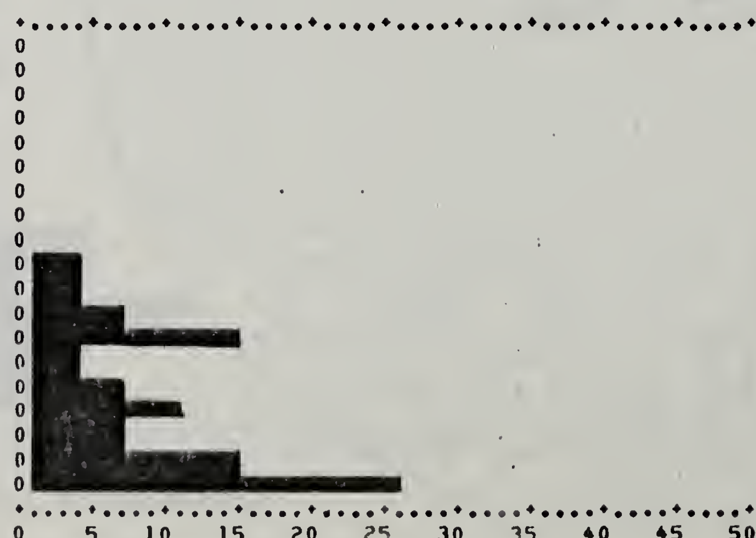


FIGURE 5.2.8-2

Strike and Dip Histograms for C-b 960 Pump Station

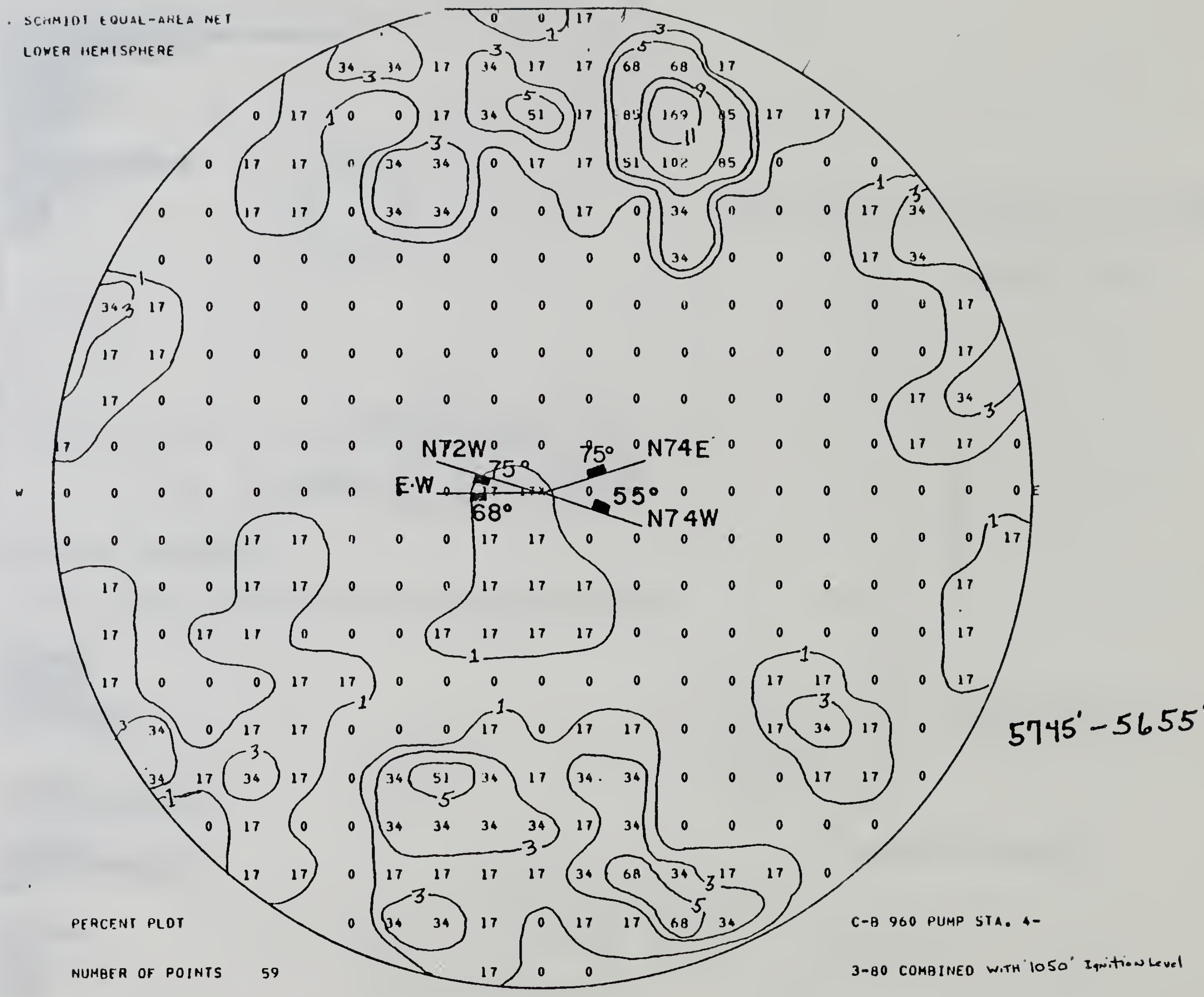


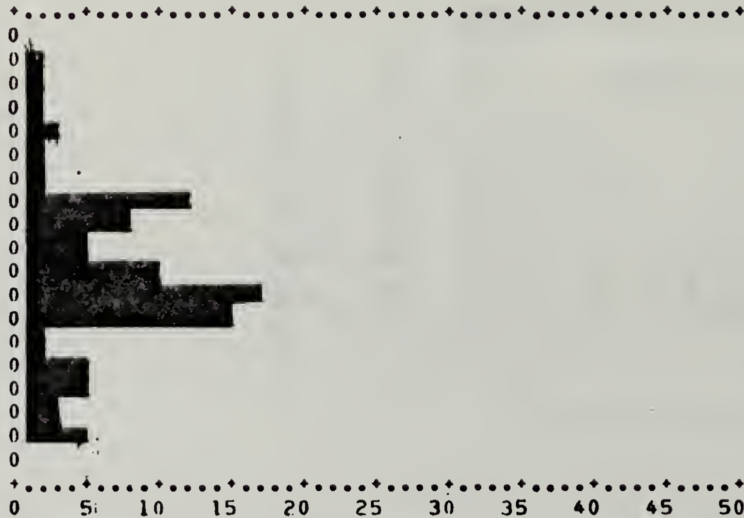
FIGURE 5.2.8-3

Stereographic Plot for C-b 960 Pump Station
Combined with 1050 Station (Old Ignition Level)

1

STRIKE HISTOGRAM

AZ	NO	PCT
0	0	0.0
10	1	1.7
20	1	3.4
30	1	5.1
40	2	8.5
50	1	10.2
60	1	11.9
70	7	23.7
80	5	32.2
90	3	37.3
100	6	47.5
110	10	64.4
120	9	79.7
130	1	81.4
140	3	86.4
150	3	91.5
160	2	94.9
170	3	100.0
180	0	100.0
TOTAL	59	

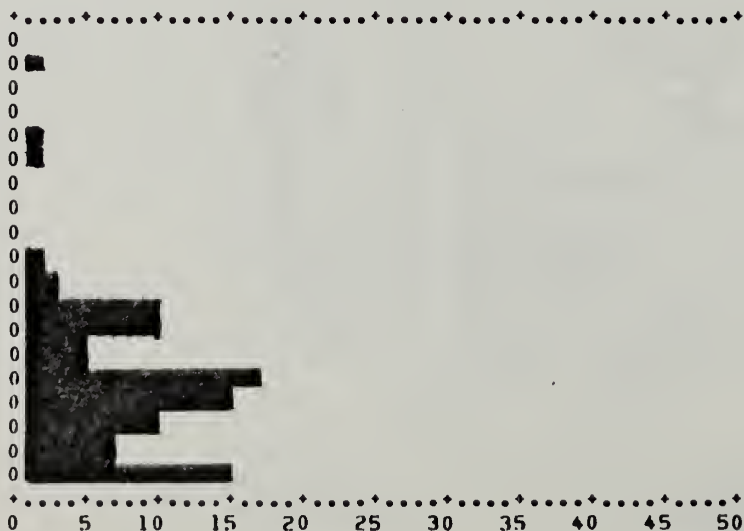


PERCENT OF OBSERVATIONS

960 Pump Station combined with
1050 Station(Old Ignition Level)

DIP HISTOGRAM

DIP	NO	PCT
0	0	0.0
5	1	1.7
10	0	1.7
15	0	1.7
20	1	3.4
25	1	5.1
30	0	5.1
35	0	5.1
40	0	5.1
45	1	6.8
50	2	10.2
55	6	20.3
60	6	30.5
65	3	35.6
70	10	52.5
75	9	67.8
80	6	78.0
85	4	84.7
90	9	100.0
TOTAL	59	



PERCENT OF OBSERVATIONS

FIGURE 5.2.8-4

Strike and Dip Histograms for 960 Pump Station
Combined with 1050 Station (Old Ignition Level)

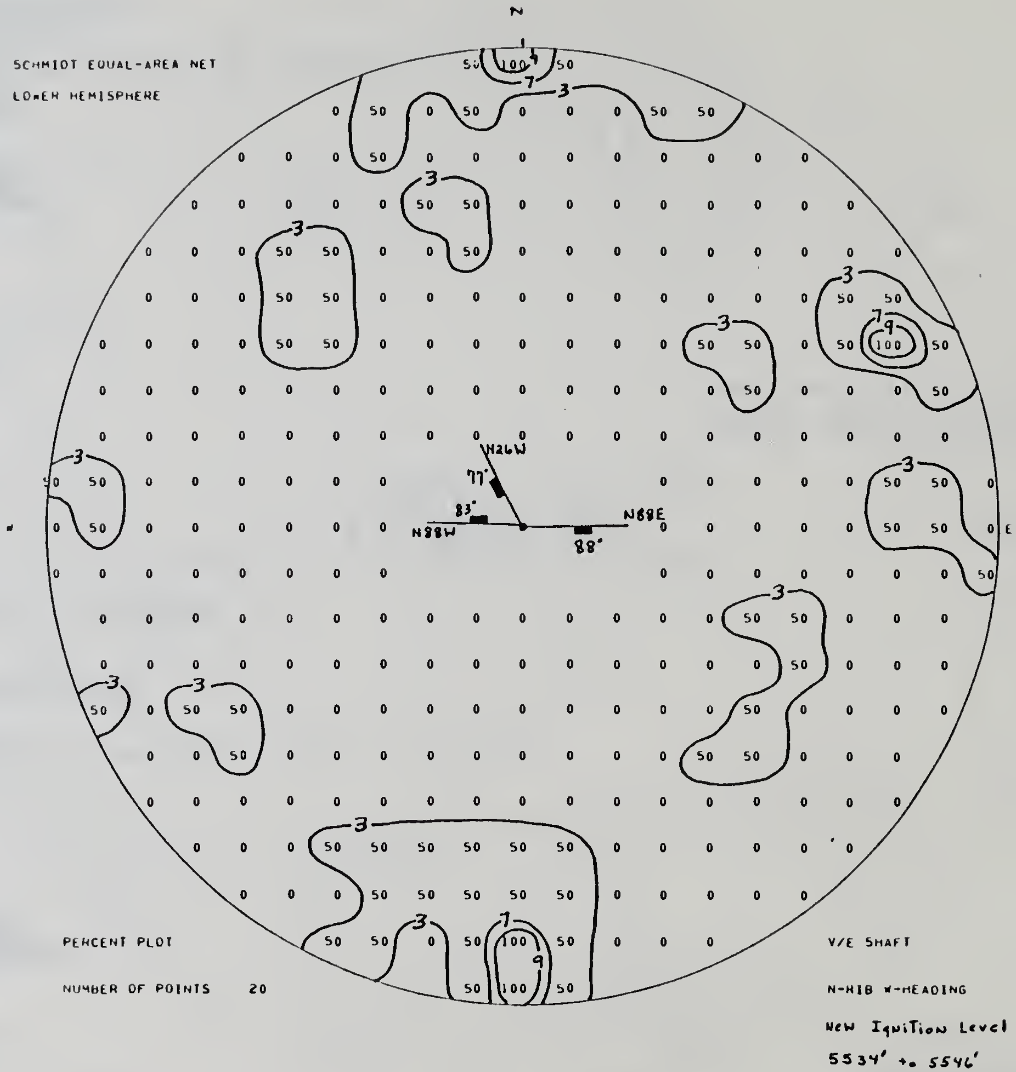


FIGURE 5.2.8-5

Stereographic Plot for V/E Shaft

```
                              STRIKE HISTOGRAM
 AZ  NO   PCT
                +....+....+....+....+....+....+....+....+....+....+
  0   1    5.0  011111
 10   1   10.0  011111
 20   1   15.0  011111
 30   0   15.0  0
 40   1   20.0  011111
 50   2   30.0  01111111111
 60   0   30.0  0
 70   1   35.0  011111
 80   3   50.0  0111111111111111
 90   2   60.0  01111111111
100   2   70.0  01111111111
110   1   75.0  011111
120   1   80.0  011111
130   0   80.0  0
140   1   85.0  011111
150   2   95.0  01111111111
160   1  100.0  011111
170   0  100.0  0
180   0  100.0  0
                +....+....+....+....+....+....+....+....+....+....+
   TOTAL    20  0    5   10   15   20   25   30   35   40   45   50

                PERCENT OF OBSERVATIONS

                              DIP    HISTOGRAM
DIP  NO   PCT
                +....+....+....+....+....+....+....+....+....+....+
  0   0    0.0  0
  5   0    0.0  0
 10   0    0.0  0
 15   0    0.0  0
 20   0    0.0  0
 25   0    0.0  0
 30   0    0.0  0
 35   0    0.0  0
 40   0    0.0  0
 45   0    0.0  0
 50   2   10.0  01111111111
 55   1   15.0  011111
 60   4   35.0  011111111111111111111
 65   3   50.0  0111111111111111
 70   0   50.0  0
 75   3   65.0  0111111111111111
 80   3   80.0  0111111111111111
 85   3   95.0  0111111111111111
 90   1  100.0  011111
                +....+....+....+....+....+....+....+....+....+....+
   TOTAL    20  0    5   10   15   20   25   30   35   40   45   50

                PERCENT OF OBSERVATIONS

                                     V/E SHAFT NEW IGIN
                                     N-RIB W-HEADING
```

FIGURE 5.2.8-6

Strike and Dip Histograms for V/E Shaft

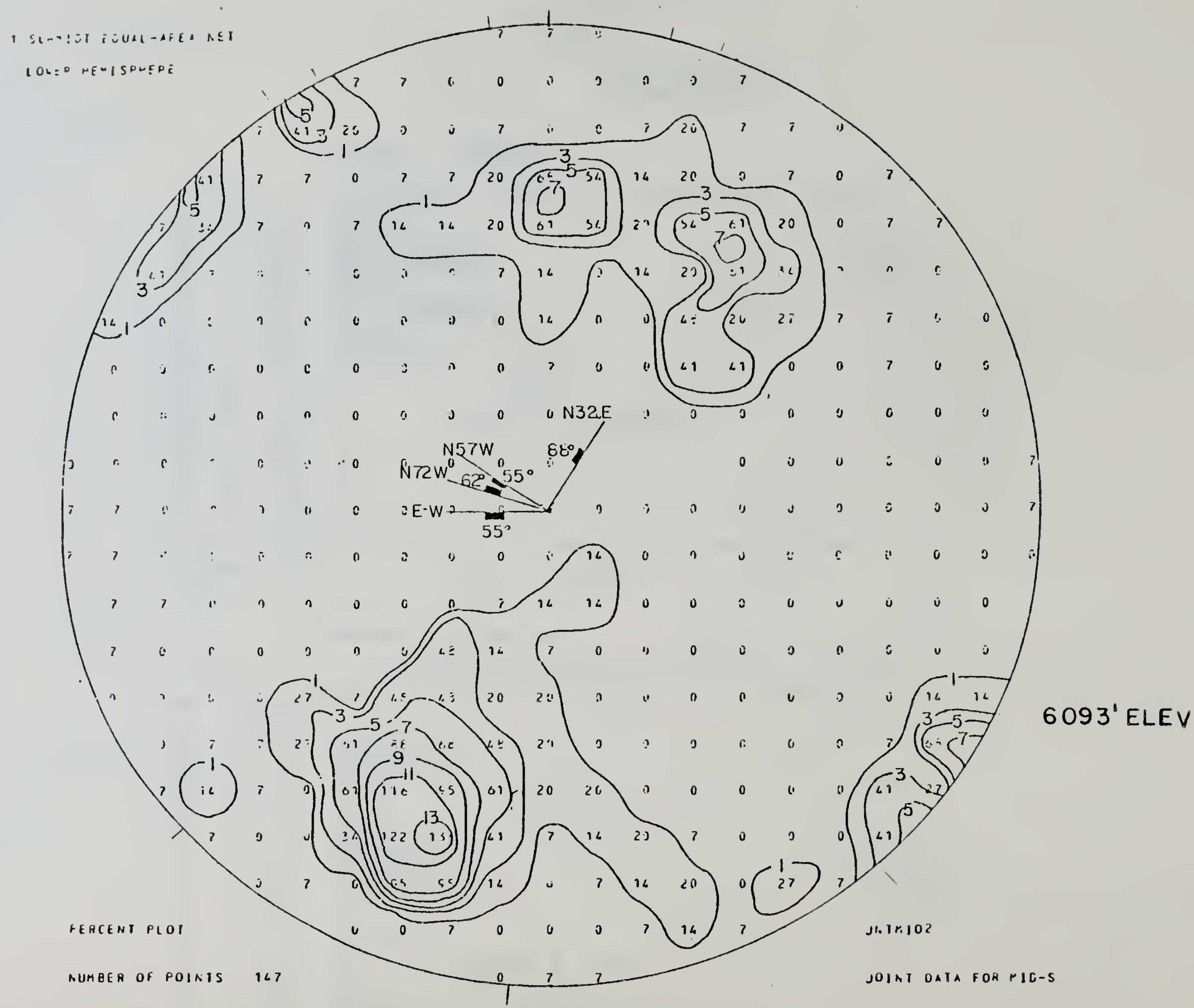
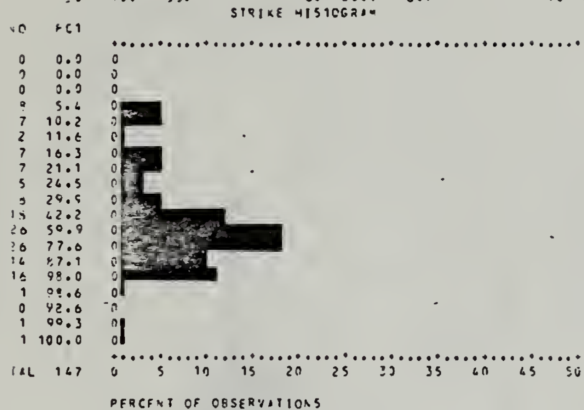


FIGURE 5.2.8-7

Stereographic Plot for Mid Shaft Station Joint Data

	STRIKE	DIP		STRIKE	DIP		STRIKE	DIP		STRIKE	DIP		STRIKE	DIP
1	285.	45.	31	95.	55.	61	265.	50.	91	245.	15.	121	217.	86.
2	285.	47.	32	95.	55.	62	55.	52.	92	245.	15.	122	215.	79.
3	285.	47.	33	95.	55.	63	260.	60.	93	250.	66.	123	295.	43.
4	270.	39.	34	95.	55.	64	70.	62.	94	115.	80.	124	90.	30.
5	275.	38.	35	95.	55.	65	60.	55.	95	135.	54.	125	207.	85.
6	275.	38.	36	95.	55.	66	112.	52.	96	130.	59.	126	207.	35.
7	290.	58.	37	140.	55.	67	250.	70.	97	125.	52.	127	135.	54.
8	135.	35.	38	305.	54.	68	300.	60.	98	280.	52.	128	287.	68.
9	135.	35.	39	140.	55.	69	22.	60.	99	115.	53.	129	287.	65.
10	135.	35.	40	305.	54.	70	355.	55.	100	60.	90.	130	297.	65.
11	135.	35.	41	95.	55.	71	254.	66.	101	290.	54.	131	285.	70.
12	135.	35.	42	320.	55.	72	70.	86.	102	110.	65.	132	285.	72.
13	135.	35.	43	80.	52.	73	150.	68.	103	280.	63.	133	60.	90.
14	305.	55.	44	125.	58.	74	55.	61.	104	60.	87.	134	45.	90.
15	305.	55.	45	295.	52.	75	60.	23.	105	280.	53.	135	55.	90.
16	305.	55.	46	295.	58.	76	110.	74.	106	280.	58.	136	295.	50.
17	120.	88.	47	263.	61.	77	40.	90.	107	280.	58.	137	300.	35.
18	300.	68.	48	125.	62.	78	265.	50.	108	30.	90.	138	300.	35.
19	270.	42.	49	80.	44.	79	45.	90.	109	30.	90.	139	300.	35.
20	290.	70.	50	290.	60.	80	40.	90.	110	30.	90.	140	300.	35.
21	290.	72.	51	124.	58.	81	290.	50.	111	30.	90.	141	300.	35.
22	290.	70.	52	129.	68.	82	280.	50.	112	30.	90.	142	310.	44.
23	290.	70.	53	115.	62.	83	60.	37.	113	30.	90.	143	290.	22.
24	290.	70.	54	120.	58.	84	300.	60.	114	40.	90.	144	300.	35.
25	290.	70.	55	125.	52.	85	320.	50.	115	40.	90.	145	130.	44.
26	290.	70.	56	290.	65.	86	43.	90.	116	290.	32.	146	252.	85.
27	315.	60.	57	345.	30.	87	280.	68.	117	298.	43.	147	295.	52.
28	315.	60.	58	119.	58.	88	90.	39.	118	298.	[illegible]	148	0.	0.
29	315.	60.	59	125.	55.	89	320.	74.	119	298.	43.	149	0.	0.
30	95.	55.	60	300.	60.	90	255.	66.	120	110.	53.	150	0.	0.



MID SHAFT STATION JOINT DATA

ELEV. 6105'

FIGURE 5.2.8-8

Strike and Dip Histograms for Mid Shaft Station Joint Data

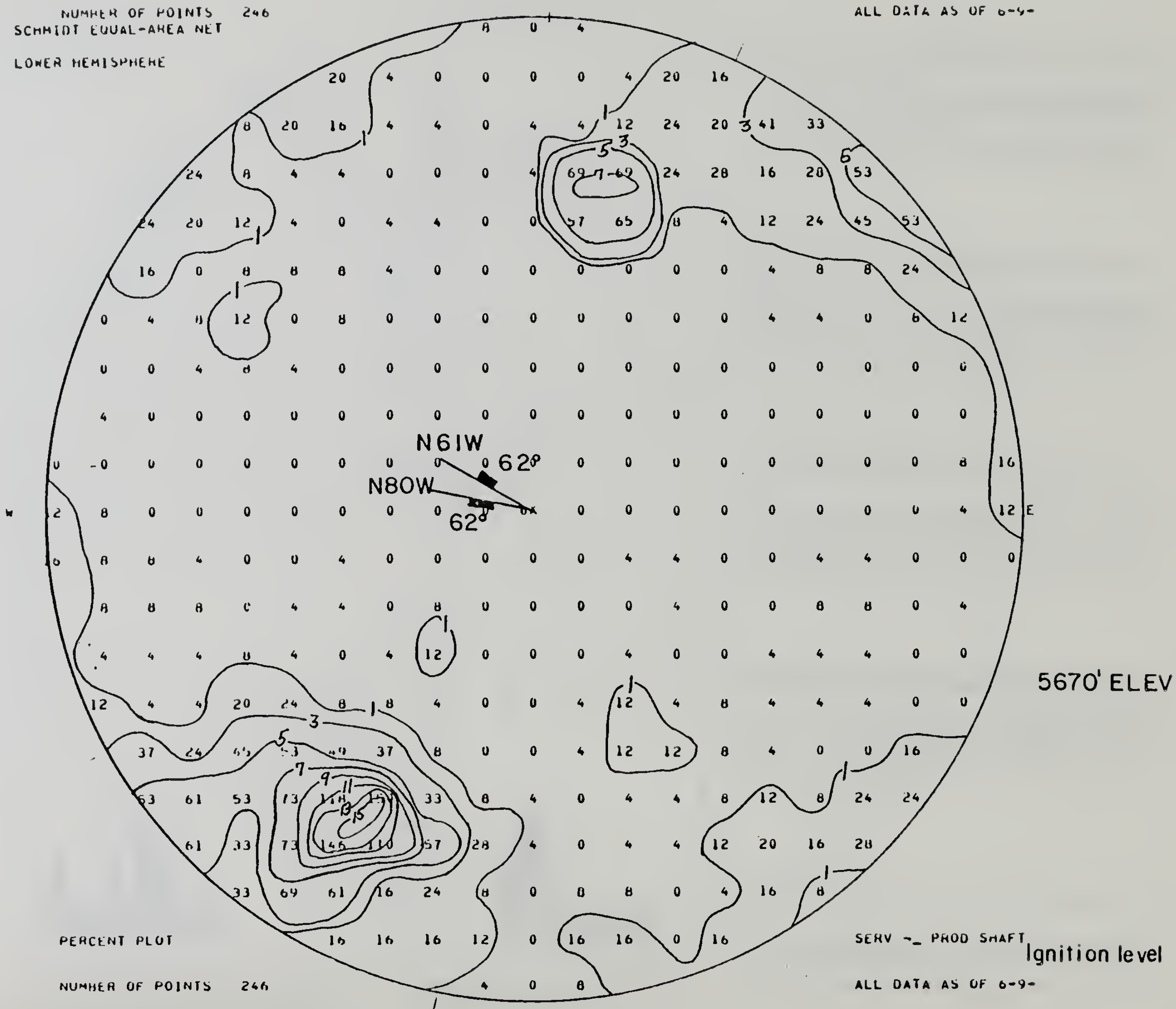
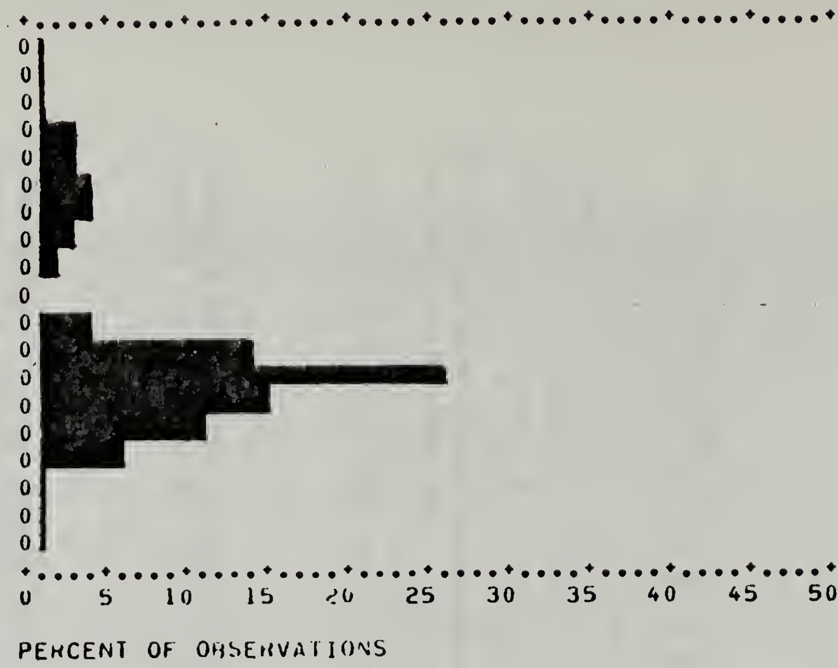


FIGURE 5.2.8-9

Stereographic Plot for Ignition Level, Service and Production Shaft

AZ	0	PCT
0	2	.8
10	2	1.6
20	2	2.4
30	7	5.3
40	8	8.5
50	11	13.0
60	9	16.7
70	7	19.5
80	4	21.1
90	0	21.1
100	9	24.8
110	35	39.0
120	63	64.6
130	36	79.3
140	28	90.7
150	15	96.7
160	3	98.0
170	3	99.2
180	2	100.0
TOTAL	246	



DIP HISTOGRAM

DIP	NO	PCT
0	0	0.0
5	0	0.0
10	0	0.0
15	0	0.0
20	0	0.0
25	3	1.2
30	0	1.2
35	3	2.4
40	3	3.7
45	1	4.1
50	4	5.7
55	37	20.7
60	29	32.5
65	41	49.2
70	25	59.3
75	22	68.3
80	16	74.8
85	26	85.4
90	36	100.0
TOTAL	246	

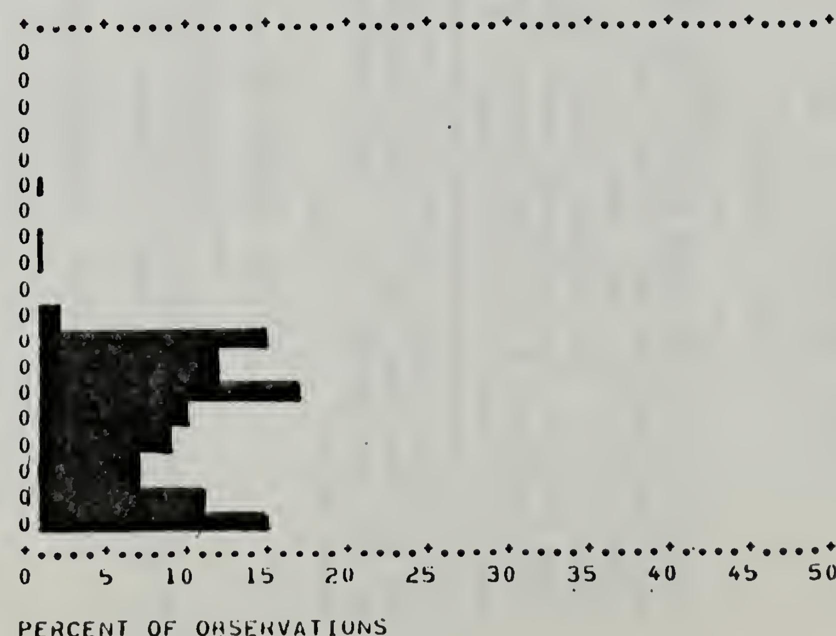


FIGURE 5.2.8-10

Strike and Dip Histograms for Ignition Level, Service and Production Shaft

Water production in the V/E shaft increased from 110 to 160 gpm during the development of the station at 960 feet. At the 1050 foot station water production increased from 165 to 490 gpm mainly through leached vugs previously described. The largest water increase was encountered in the Ignition Level station. Water production increased from 335 to 830 gpm. No water was encountered in the Mahogany Zone.

Total inflow from the Service and Production shafts as of December was approximately 450 gpm. Probing performed during the year failed to encounter any major flows through the bottom of either shaft.

5.3 Water Quality

5.3.1 Streams

5.3.1.1 Scope

The spatial limits of the stream quality monitoring program are from the USGS station WU07 upstream from the C-b Tract to USGS WU00 downstream and west of the Tract. The locations of these stations and other USGS stations were shown previously on Figure 5.2.1-1 and described in Table 5.2.1-1. The program includes stations on streams tributary to Piceance Creek that are on or adjacent to the Tract. The sampling frequency and parameters measured at USGS stations are shown in Tables 5.3.1-1 and 5.3.1-2. The sampling intervals for the stream monitoring program are shown in Figure 5.3.1-1. The Water Augmentation Plan requires measurements of water quality at USGS stations identified previously in Table 5.2.1-1. The water quality data for stations other than the major stations are provided in Appendix Tables A5.3.1-1 through A5.3.1-3. Water quality data for the major stations are discussed below.

5.3.1.2 Objectives

The surface stream water quality monitoring program was implemented to detect changes in water quality, and if changes are detected, to investigate the cause for change.

5.3.1.3 Experimental Design

Data from the monitoring network were collected and analyzed according to the schedules and parameters noted in Tables 5.3.1-1 and 5.3.1-2. In addition to the laboratory analyses listed in Tables 5.3.1-1 and 5.3.1-2, measurements of flow, temperature and specific conductance were made at all stations. At the four major stations on perennial streams, pH and dissolved oxygen are measured and recorded at the two Piceance Creek stations. Suspended sediment samples are obtained at Stations WU07, WU22, WU39, WU58, and WU61. All water quality samples are analyzed by procedures previously used during the Environmental Baseline Study. Analysis and data verification for the USGS stations are performed by the USGS laboratories in Denver and by the USGS Subdivision office in Meeker. Samples for streambed sediment characterization were taken at Station WU42.

TABLE 5.3.1-1

WATER SAMPLING FREQUENCY REQUIREMENTS
MAJOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$			●			
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_3			●			
Antimony							
Arsenic	As			●			
Bacteria	SB						
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3			●			
Biological Oxygen Demand	BOD				●		
Bismuth	Bi						
Boron	B			●			
Bromine	Br				●		
Cadmium	Cd				●		
Calcium	Ca			●			
Carbonate	CO_3			●			
Chemical Oxygen Demand	COD				●		
Chloride	Cl			●			
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal					●		
Coliform, Total					●		
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC	●					
Copper	Cu				●		
Cyanide	Cn				●		
Dissolved Oxygen	DO						
Element Scan					●		
Fecal Streptococcus					●		
Flow		●					
Fluoride	F			●			
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe			●			
Kjeldahl Nitrogen				●			
Lead	Pb				●		
Level							
Lithium	Li				●		
Magnesium	Mg			●			
Manganese	Mn			●			
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS					●	
Molybdenum	Mo				●		
Nickel	Ni						
Nitrate	NO_3			●			
Nitrite	NO_2			●			
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC			●			
Organic Carbon, Total	TOC			●			
Ortho-Phosphorus (Phosphate)	PO_4				●		
Pesticides						●	
pH	pH	●					
Phenols				●			
PNA	PNA						
Potassium	K			●			
Rubidium	RB						
Sediment Characterization							
Selenium	Se				●		
Scandium	SC						
Silica	SiO_2			●			
Silver	Ag						
Sodium	Na			●			
Solids, Dissolved	TDS			●			
Solids, Suspended	SOLS				●		
Strontium	Sr						
Surfactants							
Sulfate	SO_4			●			
Sulfide	SO_2				●		
Temperature (°C)		●					
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity		►					
Vanadium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity					●		
Gross Alpha (pci)							
Radium 226	Ra226						
Natural Uranium	U				●		
Gross Beta							
Cesium	Cs137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* DMP and WAP stations WU07, WU22, WU58, WU61.

SYMBOLS

● Applies to all stations (DMP and WAP).

► Applies to stations WU07 and WU61 only.

TABLE 5.3.1-2

WATER SAMPLING FREQUENCY REQUIREMENTS
MINOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$				●			
MA Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al				●			
Ammonia	as NH_3				●			
Antimony								
Arsenic	As				●			
Bacteria	SB							
Barium	Ba				●			
Beryllium	Be				●			
Bicarbonate	HCO_3							
Biological Oxygen Demand	BOD				●			
Bismuth	Bi							
Boron	B				●			
Bromine	Br				●			
Cadmium	Cd				●			
Calcium	Ca				●			
Carbonate	CO_3				●			
Chemical Oxygen Demand	COD				●			
Chloride	Cl				●			
Chromium	Cr				●			
Cobalt	Co							
Coliform, Fecal					●			
Coliform, Total					●			
Color (Not Precise)								
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC							
Copper	Cu				●			
Cyanide	Cn				●			
Dissolved Oxygen	DO							
Element Scan					●			
Fecal Streptococcus					●			
Flow					●			
Fluoride	F				●			
Gallium	Ga							
Germanium	Ge							
Hardness (Ca, Mg)								
Hydroxides	OH							
Iodine	I							
Iron	Fe				●			
Kjeldahl Nitrogen					●			
Lead	Pb				●			
Level								
Lithium	Li				●			
Magnesium	Mg				●			
Manganese	Mn				●			
Mercury	Hg				●			
Methylene Blue Active Substance	MBAS							
Molybdenum	Mo				●			
Nickel	Ni							
Nitrate	NO_3				●			
Nitrite	NO_2				●			
Odor								
Oil & Grease	OLGR				●			
Organic Carbon, Dissolved	DOC				●			
Organic Carbon, Total	TOC				●			
Ortho-Phosphorus (Phosphate)	PO_4				●			
Pesticides								
pH	pH				●			
Phenols					●			
PNA	PNA							
Potassium	K				●			
Rubidium	Rb							
Sediment Characterization							▶	
Selenium	Se				●			
Scandium	SC							
Silica	SiO_2				●			
Silver	Ag							
Sodium	Na				●			
Solids, Dissolved	TDS				●			
Solids, Suspended	SOLS							
Strontium	Sr				●			
Surfactants								
Sulfate	SO_4				●			
Sulfide	SO_2				●			
Temperature (°C)					●			
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti							
Tungsten	W							
Turbidity								
Vanadium	V							
Yttrium	Y							
Zinc	Zn				●			
Zirconium	Zr							
Radioactivity								
Gross Alpha (pci)					●			
Radium 226	Ra226							
Natural Uranium	U							
Gross Beta					●			
Cesium	Ce137							
Sr90								
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. Hydrophobic Bases								
b. Hydrophobic Acids								
c. Hydrophobic Neutrals								
d. Hydrophilic Bases								
e. Hydrophilic Acids								
f. Hydrophilic Neutrals								

* DMP stations WU15, WU25, WU28, WU33, WU36, WU39, WU42, WU50, WU52. WAP stations are all DMP stations + stations 4800, 6200, 6222, 6225.

SYMBOLS

● Applies to all stations (DMP and WAP).

▶ Applies to station WU42 only.

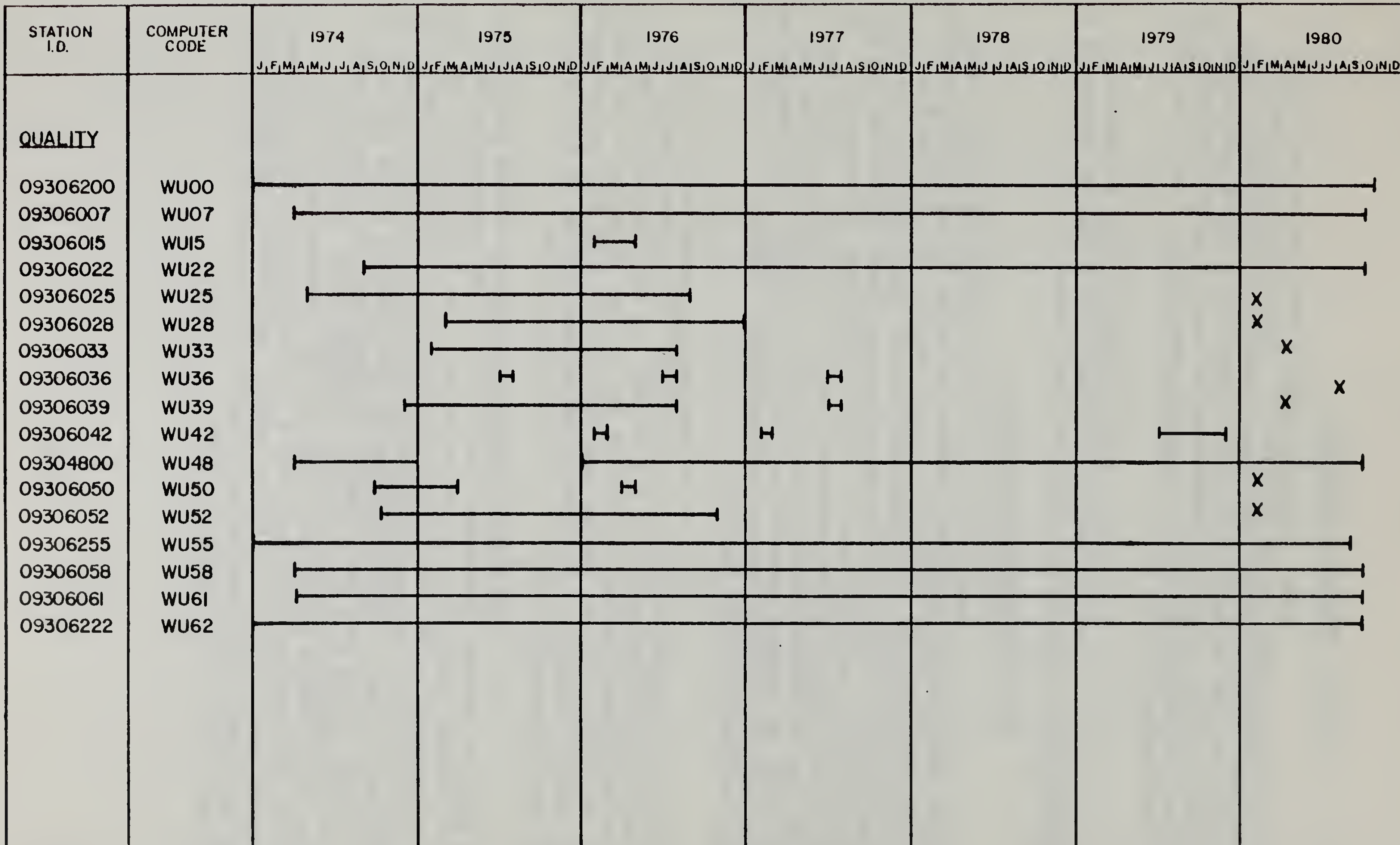


FIGURE 5.3.1-1
U.S.G.S. STREAM GAUGING STATIONS
SAMPLING TIME INTERVALS
FOR WATER QUALITY

5.3.1.4 Methods of Analysis

Linear regression analyses were used as an initial screening technique to test for the existence of linear trends with time. Histograms were also used for the statistical analyses of stream quality data. Paired t-tests are used to test the equality between two distinct population means of some variable. Histogram comparisons are used to compare variables for stations over time as well as station-to-station comparisons of variables during the same time interval.

Techniques utilized in water quality analyses are shown in Table 5.3.1-3. All statistical tests were run to test an acceptance of a null hypothesis at a five percent level of significance.

5.3.1.5 Discussion and Results

Table 5.3.1-4 lists mean, maximum and minimum values for selected water quality parameters for the four major stream gauging stations and for WU42 which monitors effluent discharges from C-b (via East No Name Creek) into Piceance Creek. Histograms and plots of these parameters with time are in the Appendix. At the two stations on Piceance Creek the maximum and minimum concentrations occurred primarily on three days during the water year. At WU07 most of the minimum readings were obtained on May 15, 1980. May 14 was a significant day for minimum concentrations at WU61. At Station WU61 the most significant day for maximum concentrations was July 16, 1980. This same day was one of two days with maximum readings at Station WU07. Section 5.3.6 discusses parameters analyzed for NPDES compliance.

At WU07 the minimum readings occurred on the sixth consecutive day of greater than 100 cfs daily mean. The maximum flow for the year at WU07 occurred on May 17. At Station WU61 the maximum flow for the year as well as the historic maximum occurred on May 13, one day prior to the sampling day. The majority of the maximum concentrations at WU07 occurred during the low flow period in November. The majority of maximum readings at WU61 occurred during a low flow period in July.

The maximum and minimum readings at WU42 occurred at various dates and reflect discharges from Tract C-b. The chemistry of the waters of Piceance Creek are a function of natural flow conditions for the most part. One exception is the concentration of fluoride at WU61 which doubled during the period July to September 1980. Prior to July the average fluoride concentration was 0.6 mg/l. One explanation for this increase is the effluent discharge into the stream past WU52; however, evidence for this effect is weak since the 1980 average is 0.8 and baseline average is 0.9. The rate of discharge itself doubled during the latter half of the water year. This increase in discharge was coincident with a decrease in actual flow in Piceance Creek magnifying the effect of effluent loading. By October, the beginning of the 1981 water year, the streamflow and fluoride concentration at Station WU61 had decreased below that of September, 1980.

TABLE 5.3.1-3

Statistical Techniques Used in Water Quality Analyses

Hydrology Subsections	Analysis Performed
5.3.1 USGS Stations	A B D F G
5.3.2 Springs and Seeps	F G
5.3.3 Alluvial Wells	F G
5.3.4 Upper and Lower 5.3.5 Aquifers	F G
5.3.6 Impoundments	B F G
Correlations Suggested under Water Augmentation Plan	B D F

Key:
- A. Time Series Plots
- B. Linear Regression Analysis
- D. Histogram Analysis
- F. Tables
- G. Visual Analysis of Tables and Graphs

TABLE 5.3.1-4

Mean, Maximum and Minimum Values for Selected Constituents
Surface Water, Tract C-b (mg/l)

Station	TDS		Mg		Ca		Na		SO_4		ALK		B		F	
WU07																
Mean	666		44		68		111		177		386		0.18		0.8	
Max	873	11/14	68	11/14	83	11/14	140	7/16	340	11/14	460	7/16	0.28	7/16	1.1	7/16
Min	466	5/15	29	5/15	55	4/24	63	5/15	120	5/15	270	5/15 4/24	0.08	11/14	0.2	11/14
WU61																
Mean	782		55		70		128		240		412		0.19		0.8	
Max	965	7/16	74	7/16	82	7/16	170	6/12	310	7/16	520	7/16	0.25	7/16	1.5	8/18
Min	510	5/14 2/19	34	5/14	48	2/19	76	5/14	130	5/14	260	2/19	0.11	5/14	0.2	6/12
WU22																
Mean	885		69		86		125		334		405		0.10		0.4	
Max	956	12/13	74	7/16	95	6/12	130		370	12/13	450	6/12	0.20	11/14	1.1	11/14
Min	691	11/14	55	2/19	73	11/14	120		180	11/14	380	8/18	0.08		0.2	6/12
WU58																
Mean	834		67		86		112		312		377		0.13		0.4	
Max	944	7/16	74	7/16	98	12/13	130	7/16	350	5/6	460	7/16	0.19	7/16	0.07	7/16
Min	699	2/19	55	2/19	71	5/6	92	2/19	240	2/19	240	5/6	0.10	12/13	0.1	6/12
WU42																
Mean	1093		14		24		354		296		548		4.93		6.9	
Max	1520	8/18 9/15	17	1/20	39	1/20	600	8/18	430	1/20	1110	8/18	8.00	8/18	17.0	7/16
Min	491	2/19	6.7	9/15	15	8/18	120	2/19	140	2/19	190	10/18	1.90	10/18	0.6	6/12

The baseline fluoride concentrations at Station WU07 and WU61 were 0.9 mg/l. For the 1980 water year the mean concentration for these stations was 0.8 mg/l.

Table 5.3.1-5 compares baseline mean values for major constituents and the mean values for the 1980 water year at the major stations. Ratios of constituent concentrations at WU61 and WU07 are presented in Table 5.3.1-6. A major difference in these ratios is found in the ammonia concentration at WU61. This is most likely attributed to ranching operations in the valley along Piceance Creek above WU61.

Table 5.3.1-7 shows the results of the application of a linear regression model to the water quality data from major USGS stations. Four items are shown and are identified in the table footnotes: mean and number of observations, the alpha level to be compared with the selected alpha of 0.05, the slope of the regression line, and the r-square value. The omission of items three and four indicates that the linear model did not fit the data at the 0.05 level of significance. Short-term linear trends were shown in temperature and pH at all four stations. Temperature varies seasonally and therefore displays short-term trends. The slope of the regression line for pH with respect to time was essentially zero. Dissolved oxygen showed a slight negative trend at three of the four stations; these trends reflect the temperature dependence of dissolved oxygen content. Arsenic showed a positive trend at only one station, WU07, upstream from the Tract. No trends were seen for the other three stations. WU22, upstream from the C-b Tract, showed a positive linear trend in dissolved organic carbon. No short-term linear trends were shown for boron, fluoride, sodium, total dissolved solids, sulfate, specific conductivity, or ammonia.

5.3.2 Springs

5.3.2.1 <u>Scope</u>

As discussed in 5.2.2, there is a substantial contribution to Piceance Creek by springs during periods of low stream flow. There is no documentation on spring sources, and the hydrologic relationships are imperfectly known. Although no springs are known to exist on the Tract, there are several nearby that may or may not be affected by significant changes in the groundwater system caused by dewatering activities.

Water quality data were gathered during the baseline phase, and new springs were added by the requirements of the Water Augmentation Plan. Spring locations were shown previously as Figure 5.2.2-1. Parameters and sampling frequency for water quality of springs are shown in Table 5.3.2-1, and sampling intervals are shown in Figure 5.3.2-1.

5.3.2.2 <u>Objectives</u>

Objectives in monitoring the water quality of springs are to provide data for the investigation of spring sources, for the investigation of changes or trends in spring water quality, and to determine whether these changes are related to C-b development.

TABLE 5.3.1-5

Comparisons of 1980 Water Year vs. Baseline for
Mean Values of Major Constituents

Baselines are mean values
Station values are 12-month averages, 10/79 - 9/80

	WU07		WU22		WU58		WU61	
	1979-80	Baseline	1979-80	Baseline	1979-80	Baseline	1979-80	Baseline
Alk	386	422	405	403	377	402	412	465
NH_3	0.04	0.04	0.02	0.02	0.07	0.02	0.07	0.03
As	0.0031	0.0024	0.0018	0.0010	0.0020	0.0011	0.0030	0.0023
B	0.184	0.209	0.104	0.108	0.130	0.210	0.187	0.214
Ca	68	69	86	93	86	92	70	78
Cl	11.6	15	6.9	7.2	10.8	11.5	11.5	14
F	0.8	0.9	0.4	0.3	0.4	0.4	0.8	0.9
Mg	44	46	69	76	67	76	55	67
Mn	45	46	9	10	12	14	34	66
DOC	13.6	-	10.9	-	8.7	-	16.7	-
K	3.2	3.6	1.5	1.6	2.2	2.2	3.5	3.5
Si	16	15	14	15	16	15	16	17
Na	111	122	125	124	112	128	128	150
TDS	667	692	885	936	835	926	782	902
SO_4	177	164	133	368	313	356	240	290

Values are in mg/l

Station values in 1979-80 are for the months of 10/79 to 9/80 from U.S.G.S. water analyses.

Baseline values are for the period 11/74 to 10/76 - from environmental baseline program.

TABLE 5.3.1-6

Ratios of 12 month means, 10/79 - 9/80

	1979-80, WU61/WU07	Baseline, WU61/WU07
Alk	1.06	1.10
NH_3	1.75	0.75
As	0.97	0.96
B	1.02	1.02
Ca	1.03	1.13
Cl	0.99	0.93
F	1.00	1.00
Mg	1.20	1.46
Mn	0.76	1.43
K	1.09	0.97
Si	1.00	1.13
Na	1.15	1.23
SO_4	1.36	1.77
TDS	1.17	1.30

From U.S.G.S. stream monitoring data, 1979-80, and Oil Shale Tract C-b Environmental Baseline Program.

TABLE 5.3.1-7

SHORT TERM REGRESSION ANALYSIS FOR MAJOR USGS STATIONS FOR WATER YEAR 1980

Dependent Variable		WU07	WU22	WU58	WU61
TEMP	1.	8.0000/12	9.4545/11	8.9167/12	8.9667/12
	2.	0.0098	0.0129	0.0019	0.0020
	3.	0.0397	0.0265	0.0403	0.0439
	4.	0.5026	0.5152	0.6347	0.6323
FLOW	1.	11.4167/12	1.9545/11	4.9342/12	37.0417/12
	2.	0.2248	0.5554	0.1641	0.4993
	3.				
	4.				
COND	1.	1037.5000/12	1275.0000/11	1254.1667/12	1180.4583/12
	2.	0.2705	0.6412	0.6197	0.8512
	3.				
	4.				
DO	1.	9.7167/12	10.3000/11	9.4500/12	9.1250/12
	2.	0.0780	0.0071	0.0189	0.0159
	3.		-0.0095	-0.0075	-0.0069
	4.		0.5714	0.4388	0.4564
PH	1.	8.1333/12	8.2455/11	8.1917/12	8.1542/12
	2.	0.0036	0.0001	0.0175	0.0283
	3.	-0.0015	-0.0017	-0.0015	-0.0013
	4.	0.5382	0.8197	0.4470	
NH_3	1.	0.0208/12	0.0073/11	0.0308/12	0.0350/12
	2.	0.5093	0.5493	0.7873	0.1647
	3.				
	4.				
AS	1.	3.0833/12	1.8182/11	2.0000/12	3.0000/12
	2.	0.0465	0.4932	0.8956	0.8956
	3.	0.0035			
	4.	0.3401			

Dependent Variable		WU07	WU22	WU58	WU61
8	1.	184.1667/12	103.6364/11	130.0000/12	186.6667/12
	2.	0.2353	0.6646	0.0675	0.3302
	3.				
	4.				
F	1.	0.7500/12	0.3800/10	0.3909/11	0.7818/11
	2.	0.6279	0.2877	0.4105	0.1058
	3.				
	4.				
NA	1.	111.1667/12	124.5455/11	111.8333/12	127.7500/12
	2.	0.7941	0.8626	0.7527	0.4206
	3.				
	4.				
TDS	1.	666.7500/12	885.0909/11	834.3333/12	781.9167/12
	2.	0.3564	0.3585	0.8684	0.8648
	3.				
	4.				
SO_4	1.	176.6667/12	333.6364/11	312.5000/12	240.0000/12
	2.	0.1850	0.2961	0.6072	0.9702
	3.				
	4.				
DOC	1.	13.5818/11	11.4600/10	8.7000/11	16.7167/12
	2.	0.3220	0.0029	0.4462	0.8302
	3.		0.0376		
	4.		0.6902		

NOTE: Entries in the table mean the following:

1. Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α. ($\alpha = 0.05$)
3. Slope - slope is units per month
4. r^2 value

Entries 2 through 4 are included only if $\hat{\alpha} \leq 0.05$

TABLE 5.3.2-1

WATER SAMPLING FREQUENCY REQUIREMENTS
SPRINGS AND SEEPS STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY	
Alkalinity	$CaCO_3$				●			
M Alkalinity	MA							
P Alkalinity	PA							
Aluminum	Al				●			
Ammonia	as NH_3				●			
Antimony					●			
Arsenic	As				●			
Bacteria	SB							
Barium	Ba				●			
Beryllium	Be							
Bicarbonate	HCO_3				●			
Biological Oxygen Demand	BOD				●			
Bismuth	Bi							
Boron	B				●			
Bromine	Br						●	
Cadmium	Cd				●			
Calcium	Ca				●			
Carbonate	CO_3				●			
Chemical Oxygen Demand	COD				●			
Chloride	Cl				●			
Chromium	Cr				●			
Cobalt	Co							
Coliform, Fecal						●		
Coliform, Total						●		
Color (Not Precise)								
Cond. Hydrocarbon	CH							
Conductivity, Specific	SPC			●				
Copper	Cu				●			
Cyanide	Cn							
Dissolved Oxygen	DO			●				
Element Scan								
Fecal Streptococcus						●		
Flow			■					
Fluoride	F				●			
Gallium	Ga							
Germanium	Ge							
Hardness (Ca, Mg)					●			
Hydroxides	OH							
Iodine	I							
Iron	Fe				●			
Kjeldahl Nitrogen					●			
Lead	Pb				●			
Level								
Lithium	Li				●			
Magnesium	Mg				●			
Manganese	Mn				●			
Mercury	Hg				●			
Methylene Blue Active Substance	MBAS							
Molybdenum	Mo				●			
Nickel	Ni				●			
Nitrate	NO_3				●			
Nitrite	NO_2				●			
Odor								
Oil & Grease	OLGR				●			
Organic Carbon, Dissolved	DOC					►		
Organic Carbon, Total	TOC							
Ortho-Phosphorus (Phosphate)	PO_4							
Pesticides								
pH	pH			●				
Phenols					●			
PNA	PNA							
Potassium	K				●			
Rubidium	Rb							
Sediment Characterization								
Selenium	Se				●			
Scandium	SC							
Silica	SiO_2							
Silver	Ag							
Sodium	Na				●			
Solids, Dissolved	TDS							
Solids, Suspended	SOLS				●			
Strontium	Sr				●			
Surfactants								
Sulfate	SO_4				●			
Sulfide	SO_2							
Temperature (°C)				●				
Thiosulfite	S_2O_3							
Tin	Sn							
Titanium	Ti							
Tungsten	W							
Turbidity								
Vanadium	V							
Yttrium	Y							
Zinc	Zn				●			
Zirconium	Zr							
Radioactivity								
Gross Alpha (pci)						●		
Radium 226	Ra226					●		
Natural Uranium	U							
Gross Beta						●		
Cesium	Ce137							
Sr90								
Thorium 230	TH230							
Uranium	U							
Fractionation of Organic Carbon into								
a. Hydrophobic Bases								
b. Hydrophobic Acids								
c. Hydrophobic Neutrals								
d. Hydrophilic Bases								
e. Hydrophilic Acids								
f. Hydrophilic Neutrals								

* DMP and WAP stations WS01, WS02, WS03, WS04, WS06, WS07, WS09, WS10. Additional WAP stations CER-1, B-3, H-3, F-3, Fig. 4-A, W-4, W-9, CER-7, S-9, P3 & 3A.

SYMBOLS

- ● Applies to all DMP stations.
- ► Applies to two stations to be selected by AOSSO.
- ■ Applies to DMP and WAP stations.

Revised 1/15/80.

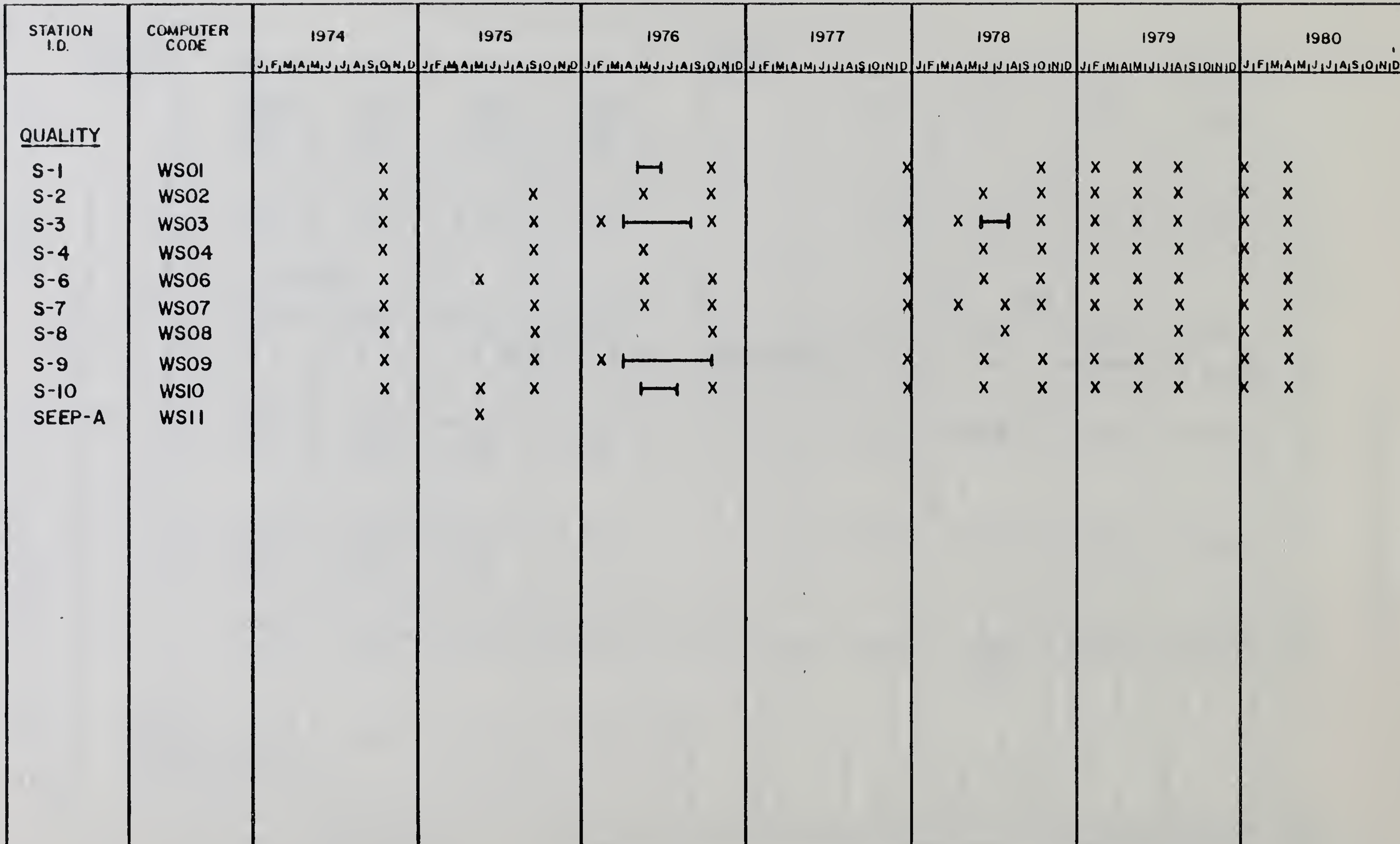


FIGURE 5.3.2-1
SPRINGS AND SEEPS SAMPLING
TIME INTERVALS FOR WATER QUALITY

5.3.2.3 Experimental Design

Water quality data from springs obtained according to the parameters and sampling frequency shown on Table 5.3.2-1 are analyzed according to methods discussed below.

5.3.2.4 Methods of Analysis

Water quality data from springs are analyzed using time series plots and a linear regression model with respect to time to identify linear trends, if any exist.

5.3.2.5 Discussion and Results

Plots of water quality parameters with respect to time are shown in the Appendix Figures A5.3.2-1 through A5.3.2-24.

Table A5.3.2-1 in the Appendix presents the results of the application of a linear regression model to the water quality data. Table 5.3.2-2 is a summary of the linear regression analysis. Inspection of the plots of water quality parameters with time, included in the Appendix as Figures A5.3.2-1 through A5.3.2-24, reveals that most appear to have a cyclical pattern. Temperature reaches a minimum several degrees below the mean in February 1980 and a maximum several degrees above the mean in June 1980. This cyclical pattern is also apparent in dissolved oxygen, which varies inversely with temperature. A cyclical pattern also appears in specific conductance values which appear higher in winter, declining to lower values in late spring and early summer, and returning to higher values in late summer and early fall.

Very few of the water quality parameters exhibit trends with time. A notable exception is arsenic, which shows a slightly negative slope in regression in eight of the springs. No cause for this trend has been determined.

Specific conductivity data (SPC), although a trend appeared in only one spring, show that means were consistently similar as were the standard deviations. Standard deviations were large, approximately twice the mean, which implied a highly skewed distribution and that springs may have a common source. In addition, the SPC values were much lower than SPC values of the wells and surface streams which indicates that the springs may be precipitation derived.

Baseline samples for fluoride for every spring were two to three times higher than any subsequently reported value. It would therefore appear that springs are showing declines in arsenic and fluoride concentrations.

5.3.3 Alluvial Wells

5.3.3.1 Scope

Alluvial wells were drilled in all gulches at C-b

TABLE 5.3.2-2

Summary of Results of Linear Regression Analysis of Water Quality Data from Springs

Parameter	Summary of Results
pH	WS06, slight negative slope, $r^2 = 0.32$
Temperature	No linear trends
Specific Conductance	WS11, positive slope, $r^2 = 0.97$
Dissolved Oxygen	No linear trends
Arsenic	WS01, WS02, WS03, WS04, WS06, WS07, WS09, WS10, all slightly negative slopes, r^2 range from 0.29 to 0.83
Fluoride	WS10, WS11, slight positive slope, $r^2 = 0.998$
Boron	WS01, WS03, WS04, WS06, WS07, all negative slopes, r^2 range from 0.03 to 0.40
Total Dissolved Solids	No linear trends
Sodium	WS03, WS06, WS07, WS11, all negative slopes, r^2 range from 0.29 to 0.998
Sulfate	WS02, WS03, both negative slopes, r^2 0.30 and 0.001, respectively.
Ammonia	WS06, negative slope, $r^2 = 0.60$

and in the major drainages of Piceance Creek, Willow Creek, and Stewart Gulch. These wells were sampled over the two-year baseline period and will be used for monitoring during development of C-b. The location of these wells were shown previously in Figure 5.2.3-1. The parameters and frequency of water quality sampling are shown in Table 5.3.3-1 and Figure 5.3.3-1 provides the sampling time intervals for alluvial wells.

In addition to the 13 alluvial wells monitored during and since baseline, one additional well was drilled and added to the monitoring network. This well, A5A, was shown previously in Figure 5.2.3-1.

5.3.3.2 Objectives

The objectives of monitoring the water quality in the alluvial wells are to ascertain if there are significant changes in the water quality in the alluvium of Piceance Creek and its tributaries on and adjacent to the Tract, and to determine if changes in water quality are attributable to activities on Tract C-b.

5.3.3.3 Experimental Design

The parameters analyzed according to the frequency shown in Table 5.3.3-2 were evaluated for water quality changes, and if significant changes occurred, to determine if these changes were due to C-b development.

5.3.3.4 Methods of Analysis

A linear regression model was applied to selected water quality data with respect to time as an initial screening technique to identify the existence of trends in water quality constituents in the alluvial wells. Plots of water quality parameters with time were analyzed subjectively.

5.3.3.5 Discussion and Results

Table 5.3.3-2 presents the 1980 mean values and the long-term mean values for selected consitituents from water quality sampling of the alluvial wells. The 1980 mean values for sodium bicarbonate and sulfate are all lower than the long-term mean values. The 1980 mean value for fluoride is equal to or lower than the long-term mean values in all wells where long-term means were available. New low values were established or existing low values were matched for fluoride, sodium and sulfate by analysis of water samples taken in July 19 and April 1980. New high values were established for calcium and TDS by analysis of water samples taken in April, May, and October 1980. The value of TDS in July 1980 matched the previous high in April 1980 and October 1974 at WA12. The new low readings in July 1980 account for 39 percent of the lowest readings for these constituents. At WA05 a slight increase in fluoride values occurred in 1980. However, these did not even approach the high values recorded in October 1974 (1.5 mg/l) and May 1975 (5.0 mg/l). A significant increase occurred in the level of calcium at WA09 in April 1980. This well is in upper Stewart Gulch in an area not possibly affected by any mining or related activity.

TABLE 5.3.3-1

WATER SAMPLING FREQUENCY REQUIREMENTS
ALLUVIAL WELLS STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$				●		
MO Alkalinity	MA						
P Alkalinity	FA						
Aluminum	Al				●		
Ammonia	as NH_3				●		
Antimony							
Arsenic	As				●		
Bacteria	SB						
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3				●		
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B				●		
Bromine	Br						●
Cadmium	Cd				●		
Calcium	Ca				●		
Carbonate	CO_3				●		
Chemical Oxygen Demand	COD				●		
Chloride	Cl				●		
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal						●	
Coliform, Total						●	
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC			●			
Copper	Cu				●		
Cyanide	Cn						
Dissolved Oxygen	DO			●			
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F				●		
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)					●		
Hydroxides	OH						
Iodine	I						
Iron	Fe				●		
Kjeldahl Nitrogen					●		
Lead	Pb				●		
Level				●			
Lithium	Li				●		
Magnesium	Mg				●		
Manganese	Mn				●		
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS						●
Molybdenum	Mo				●		
Nickel	Ni				●		
Nitrate	NO_3				●		
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH			●			
Phenols					●		
PNA	PNA						
Potassium	K				●		
Rubidium	RB						
Sediment Characterization							
Selenium	Se				●		
Scandium	SC						
Silica	SiO_2						
Silver	Ag				●		
Sodium	Na				●		
Solids, Dissolved	TDS				●		
Solids, Suspended	SOLS						
Strontium	Sr				●		
Surfactants							
Sulfate	SO_4				●		
Sulfide	SO_2						
Temperature (°C)				●			
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Ce137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* DMP and WAP stations: WA01, WA02, WA03, WA04, WA05, WA06, WA07, WA08, WA09, WA10, WA11, WA12, WA13.
Current status of wells (July 1979), WA02 and WA07 are plugged. WA04 and WA13 are dry. All others are being sampled.

SYMBOLS

● Applies to all stations (DMP and WAP).

Revised 1/15/80.

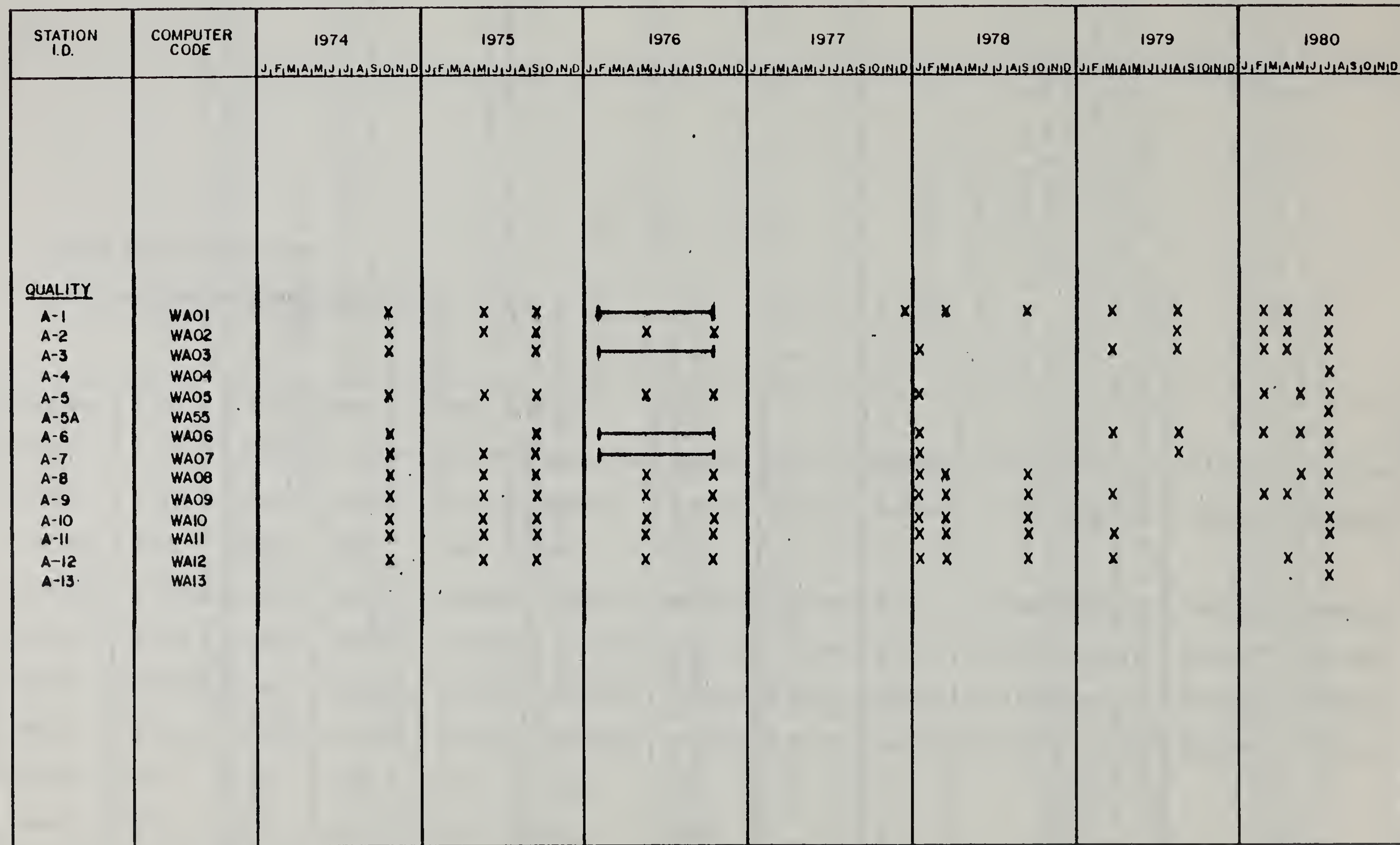


FIGURE 5.3.3-1
ALLUVIAL WELLS SAMPLING TIME
INTERVALS FOR WATER QUALITY

TABLE 5.3.3-2

Mean Values for 1980 and Long-Term Mean Values for Data from Alluvial Wells

Alluvial Well	1980/Long Term Mean						Max/Min					
	F	Ca	Na	SO_4	TDS	HCO_3	F	Ca	Na	SO_4	TDS	HCO_3
WA01*	0.9/	50/	250/	413/	1267/	590/						
WA02*	1.6/	74/	130/	283/	867/	467/						
WA03	0.4/0.5	111/89	127/134	323/352	1000/1000	483/522	1.9/0.2	170/29	250/120	430/220	1022/807	679/375
WA05	0.5/1.1	88/74	150/169	278/307	953/959	510/558	5.0/0.2	130/36	290/130	500/200	1200/851	703/440
WA06	0.5/0.5	84/66	160/181	280/320	957/1035	530/612	1.9/0.3	120/21	300/160	400/230	1200/912	741/460
WA07**	0.3/0.3	74/60	120/154	130/285	700/838	350/434	1.9/0.1	83/24	380/120	480/130	1200/696	560/250
WA08*	0.4/	122/	120/	290/	915/	415/						
WA09	0.2/0.3	86/72	107/113	297/320	830/817	370/416	0.8/0.1	140/45	150/93	450/230	960/713	480/340
WA12	0.2/0.4	126/94	140/197	370/447	1200/1139	420/515	1.7/0.1	160/50	730/130	518/310	1200/1082	617/390
WA55**	2.0/	69/	190/	250/	870/	420/						

* No long term data available.

** Only one reading 1980.

Total alkalinity values and the range of these values from all alluvial wells are similar. No time trends are exhibited. In particular, the alkalinity at WA05 upstream from the discharge point and at WA06 downstream from the discharge point are of similar value implying that effects on the water quality of the alluvium due to discharges from C-b are not apparent.

Results of the linear regression model that was applied to selected water quality data with respect to time are included in the Appendix as Table A5.3.3-1. Table 5.3.3-3 summarizes the information provided in that table. As indicated, linear trends were either not present or were negative. Even though trends are indicated in some instances, regression line slopes were near zero. Plots of the constituents with respect to time are provided in the Appendix as Figures A5.3.3-1 through A5.3.3-9.

5.3.4 Upper Aquifer Wells

5.3.4.1 Scope

The wells monitoring the water quality of the upper aquifer are the same as those used to monitor water levels. The locations of upper aquifer wells were shown previously in Figures 5.2.4-1 and 5.2.4-2.

Table 5.3.4-1 shows the parameters and sampling frequency used in the upper aquifer wells. Sampling intervals for these wells are shown in Figure 5.3.4-1.

Water quality samples require temporary reduction in water levels. The sampling schedule was adjusted to accommodate anticipated tests that were dependent upon water level data.

5.3.4.2 Objectives

The objectives of measuring the water quality in the Upper Aquifer wells are to monitor the constituents or parameters for long-term changes, and if changes become evident, to determine if they are attributable to the development of the C-b Tract.

5.3.4.3 Experimental Design

Water quality data from the Upper Aquifer wells were obtained to be used in the analysis for potential changes in water quality according to the methods discussed below.

5.3.4.4 Methods of Analysis

The analysis methods used for the water quality data from the Upper Aquifer wells were time series plots and a general linear regression model as an initial screen for water quality time changes.

TABLE 5.3.3-3
Summary of Long-Term Linear Trend Analysis
for Selected Water Quality Parameters for Tract C-b Alluvial Wells

Parameter	Results
Boron	No linear trend at any well.
Fluoride	No linear trend at any well.
Arsenic	Seven wells with negative trends: WA01, WA03, WA05, WA06, WA08, WA09, WA12.
Sulfate	Four wells with negative trends: WA06, WA07, WA10, WA12.
Sodium	One well with linear negative trend: WA06.
Ammonia	No linear trends at any well.
Molybdenum	Four wells with negative trends: WA02, WA03, WA06, WA09.
pH	One well with negative linear trend: WA12.
Temperature	No linear trend at any well.

TABLE 5.3.4-1 WATER SAMPLING FREQUENCY REQUIREMENTS
DEEP WELLS - UPPER AQUIFER*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al						
Ammonia	as NH_3					●	
Antimony						●	
Arsenic	As						
Bacteria	SB					●	
Barium	Ba						
Beryllium	Be					●	
Bicarbonate	HCO_3					●	
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B					●	
Bromine	Br						
Cadmium	Cd					●	
Calcium	Ca						
Carbonate	CO_3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl					●	
Chromium	Cr					●	
Cobalt	Co					●	
Coliform, Fecal						●	
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC						
Copper	Cu					●	
Cyanide	Cn					●	
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F					●	
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)						●	
Hydroxides	OH						
Iodine	I						
Iron	Fe					●	
Kjeldahl Nitrogen						●	
Lead	Pb					●	
Level				■			
Lithium	Li					●	
Magnesium	Mg					●	
Manganese	Mn					●	
Mercury	Hg					●	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					●	
Nickel	Ni					●	
Nitrate	NO_3					●	
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR					●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH					●	
Phenols						●	
PNA	PNA						►
Potassium	K					●	
Rubidium	Rb						
Sediment Characterization							
Selenium	Se					●	
Scandium	SC						
Silica	SiO_2						
Silver	Ag					●	
Sodium	Na					●	
Solids, Dissolved	TDS					●	
Solids, Suspended	SOLS						
Strontium	Sr					●	
Surfactants							
Sulfate	SO_4					●	
Sulfide	SO_2						
Temperature (°C)							
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn					●	
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Ce137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* C-b affiliated (DMP and WAP stations)

WX02	WX10	WX18	WX32	WX55
WX03	WX12	WX19	WX33	WX63
WX04	WX17	WX20	WX44	WX92
		WX21		

Revised 1/15/80.

Non-affiliated (Additional WAP stations)

TH75-5A	TH75-9A	Greeno 4-4	Bute 25
TH75-13A	CER RB-D-02	Oldland 3	Liberty Bell 12
TH75-18A	TH75-15A	GP-17X-BG	Union B1

SYMBOLS

● Applies to all C-b affiliated stations

► Applies to stations and species to be identified.

■ Applies to both affiliated and non-affiliated stations

STATION I.D.	COMPUTER CODE	1974 J	F	M	A	M	J	J	A	S	O	N	D
QUALITY													
CB-2	WX02											X	
CB-4	WX04											X	
SG-10A	WX10												
SG-1A	WX11												
SG-1-2	WX12												
SG-17-2	WX17												
SG-18A	WX18											X	
SG-19	WX19											X	
SG-20	WX20												
SG-21	WX21												
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44											X	
SG-11-3	WX55												
SG-6-3	WX63												
SG-8-2	WX82												
SG-9-2	WX92											X	

STATION I.D.	COMPUTER CODE	1975 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02				X						X		
CB-4	WX04				X						X		
SG-10A	WX10				X						X		
SG-1A	WX11												
SG-1-2	WX12				X						X		
SG-17-2	WX17				X						X		
SG-18A	WX18					X					X		
SG-19	WX19				X						X		
SG-20	WX20				X						X		
SG-21	WX21				X						X		
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44				X						X		
SG-11-3	WX55				X						X		
SG-6-3	WX63				X						X		
SG-8-2	WX82				X						X		
SG-9-2	WX92				X						X		

STATION I.D.	COMPUTER CODE	1976 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02										X		
CB-4	WX04										X		
SG-10A	WX10										X		
SG-1A	WX11												
SG-1-2	WX12					X					X		
SG-17-2	WX17					X					X		
SG-18A	WX18										X		
SG-19	WX19										X		
SG-20	WX20					X					X		
SG-21	WX21										X		
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44					X					X		
SG-11-3	WX55										X		
SG-6-3	WX63					X					X		
SG-8-2	WX82												
SG-9-2	WX92					X					X		

STATION I.D.	COMPUTER CODE	1977 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02											X	
CB-4	WX04											X	
SG-10A	WX10												
SG-1A	WX11												
SG-1-2	WX12											X	
SG-17-2	WX17											X	
SG-18A	WX18												
SG-19	WX19												
SG-20	WX20											X	
SG-21	WX21												
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44												
SG-11-3	WX55											X	
SG-6-3	WX63											X	
SG-8-2	WX82												
SG-9-2	WX92											X	

STATION I.D.	COMPUTER CODE	1978 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02					X						X	
CB-4	WX04					X							
SG-10A	WX10						X					X	
SG-1A	WX11												
SG-1-2	WX12					X						X	
SG-17-2	WX17					X						X	
SG-18A	WX18												
SG-19	WX19					X						X	
SG-20	WX20					X						X	
SG-21	WX21						X						
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44					X							
SG-11-3	WX55					X						X	
SG-6-3	WX63					X						X	
SG-8-2	WX82												
SG-9-2	WX92					X						X	

STATION I.D.	COMPUTER CODE	1979 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02					X							X
CB-4	WX04												X
SG-10A	WX10					X							
SG-1A	WX11												
SG-1-2	WX12					X							X
SG-17-2	WX17					X							X
SG-18A	WX18												X
SG-19	WX19					X							X
SG-20	WX20					X							
SG-21	WX21					X							X
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44					X							X
SG-11-3	WX55					X							X
SG-6-3	WX63					X							X
SG-8-2	WX82												
SG-9-2	WX92					X							X

STATION I.D.	COMPUTER CODE	1980 J	F	M	A	M	J	J	A	S	O	N	D
CB-2	WX02						X						
CB-4	WX04						X						
SG-10A	WX10												
SG-1A	WX11												
SG-1-2	WX12												
SG-17-2	WX17												
SG-18A	WX18						X						
SG-19	WX19												
SG-20	WX20												
SG-21	WX21						X						
32X-12	WX32												
33X-1	WX33												
AT-1C-3	WX44												
SG-11-3	WX55						X						
SG-6-3	WX63												
SG-8-2	WX82												
SG-9-2	WX92						X						

FIGURE 5.3.4-1
UPPER TRACT AQUIFER WELLS
SAMPLING TIME INTERVALS
FOR WATER QUALITY

5.3.4.5 Discussion and Results

Plots of water quality parameters with respect to time for Upper Aquifer wells are provided in Figures A5.3.4-1 through A5.3.4-8 in the Appendix.

Short-term analysis of water quality data for deep wells are not performed since short-term analysis require monthly or more frequent samples; Upper Aquifer wells are sampled semi-annually.

The results of the linear regression analysis with respect to time are summarized in Tables 5.3.4-2 and 5.3.4-3. The four entries for each regression are: (1) the mean value and number of observations; (2) the alpha level of significance for comparison with the selected 0.05 alpha level (alpha less than 0.05 implies correlation to the 0.05 level of significance); (3) slope of the regression line from the linear model; and (4) the r-square value. If items three and four are omitted from the table, alpha was greater than 0.05 and the linear model did not fit the data.

Boron concentrations showed a negative trend in WX02, with no trends in the other wells. Aluminum displayed negative trends at WX04 and WX19 with no trends shown for the other wells. Potassium showed negative trends at WX04 to WX21; no trends were shown in the other wells. WX10 showed a negative trend in total dissolved solids. Calcium displayed a positive trend at WX20, but no trends at the other wells. Ammonia indicated a positive trend at WX19, and magnesium showed a positive trend at WX02. Fluoride levels showed a negative linear trend in WX02, with no long-term trends in the other wells. Even though trends are indicated in these parameters for these wells, the regression line slopes are very near zero for all cases. As Table 5.3.4-2 shows, no trends were shown in any remaining wells or parameters.

5.3.5 Lower Aquifer Wells

5.3.5.1 Scope

The wells monitoring the Lower Aquifer water quality are the same as those used to monitor water levels. The locations of the Lower Aquifer wells were shown previously in Figures 5.2.4-1 and 5.2.4-2.

Table 5.3.5-1 shows the parameters and sampling frequency used in the Lower Aquifer wells. Sampling intervals for these wells are shown in Figure 5.3.5-1.

Water quality sampling may result in temporary reduction in water levels. Tests that depend upon water level data may have precluded some water quality sampling.

5.3.5.2 Objectives

The objectives of measuring the water quality in the Lower Aquifer wells are to monitor the parameters for long-term changes, and if changes become apparent, to attempt to investigate the causal relationships for the changes.

TABLE 5.3.4-2

LONG TERM TIME TREND ANALYSIS OF WATER QUALITY FOR UPPER AQUIFER WELLS

		WX02	WX04	WX10	WX18	WX19	WX20	WX21	WX44	WX82
SPC	1.	1610.3750/8	832.1429/7	1411.0000/5	765.7800/5	2777.3333/6	2163.5571/7	1020.0000/5	1365.8333/	1830.0000/3
(μmhos)	2.	0.6888	0.2464	0.0211	0.2550	0.6386	0.2762	0.3075	0.1995	0.3421
	3.									
	4.									
B	1.	0.5310/10	0.4538/8	0.6417/6	0.7000/6	1.2667/9	1.8850/8	0.2571/7	0.3786/7	1.0750/4
(mg/l)	2.	0.0458	0.1350	0.1756	0.5430	0.5953	0.6653	0.1120	0.3056	0.1930
	3.	-0.0008								
	4.	0.4109								
AL	1.	0.1538/8	0.1486/7	0.5767/6	0.0950/6	0.2034/8	0.1329/8	0.0143/7	0.2243/7	2.8750/4
(mg/l)	2.	0.0507	0.0221	0.3500	0.0712	0.0408	0.5038	0.1308	0.3584	0.4338
	3.		-0.0003			-0.0002				
	4.		0.6819			0.5292				
K	1.	2.8400/10	0.8143/8	0.8500/6	0.6833/6	1.1000/8	0.8488/8	0.5571/7	2.3375/8	0.5700/4
(mg/l)	2.	0.2535	0.0063	0.3144	0.0636	0.6641	0.4524	0.0387	0.2741	0.3096
	3.		-0.0002					-0.0003		
	4.		0.7374					0.6078		
TDS	1.	710.4700/10	400.8500/8	536.9600/5	579.5000/6	1342.6000/8	1107.4625/8	515.3167/6	768.5571/7	1300.0000/3
(mg/l)	2.	0.6279	0.5905	0.0189	0.6766	0.4015	0.1371	0.9472	0.5536	0.7227
	3.			-0.7949						
	4.			0.8778						
CA	1.	7.5700/10	20.1250/8	55.0000/6	25.6000/6	6.4889/9	6.1375/8	19.8571/7	43.7500/8	22.7250/4
(mg/l)	2.	0.3198	0.6314	0.7096	0.7437	0.2766	0.0003	0.1226	0.1740	0.7560
	3.						0.0032			
	4.						0.9018			
NH_3	1.	0.3467/9	0.4143/7	0.6483/6	0.9520/5	1.3978/9	1.6686/7	0.6800/7	0.7171/7	1.2750/4
(mg/l)	2.	0.1051	0.5234	0.1512	0.3963	0.0415	0.8660	0.4365	0.5809	0.9712
	3.					0.0006				
	4.					0.4700				
MG	1.	4.4100	19.5000/8	50.8333/6	31.8333/6	2.9667/9	3.0125/8	22.7143/7	40.6250/8	16.8250/4
(mg/l)	2.	0.0399	0.1083	0.4743	0.9359	0.9103	0.7684	0.6522	0.9737	0.0516
	3.	0.0008								
	4.	0.4288								
F	1.	1.6460/10	0.8687/8	0.6300/6	35.3500/6	21.1222/9	22.5625/8	8.6571/7	4.6250/8	14.0000/2
(mg/l)	2.	0.0480	0.6553	0.2590	0.3545	0.1465	0.8322	0.2510	0.6864	
	3.	-0.0009								
	4.	0.4047								

NOTE: Entries in the table mean the following:

1. Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α. (α = 0.05)
3. Slope - slope is units per month
4. Intercept
5. r^2 value

TABLE 5.3.4-3

Summary of Long Term Linear Regression
Water Quality Upper Aquifer

Parameter	Result
Specific Conductance	No trends exist
Boron	Only two wells with trends, both negative: WX02 WX55
Aluminum	Only two wells with trends, both negative: WX04 WX19
Potassium	Only two wells with trends, both negative: WX04 WX21
TDS	Only one well with trend, negative: WX10
Ca	Only two wells with trends, negative: WX63 positive: WX20
Ammonia	Only one well with trend, positive: WX19
Magnesium	Only two wells with trends, negative: WX63 positive: WX02

TABLE 5.3.5-1

WATER SAMPLING FREQUENCY REQUIREMENTS
DEEP WELLS - LOWER AQUIFER*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al					●	
Ammonia	as NH_3					●	
Antimony							
Arsenic	As					●	
Bacteria	SB						
Barium	Ba					●	
Beryllium	Be						
Bicarbonate	HCO_3					●	
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B					●	
Bromine	Br					●	
Cadmium	Cd						
Calcium	Ca					●	
Carbonate	CO_3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl					●	
Chromium	Cr					●	
Cobalt	Co					●	
Coliform, Fecal							
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC						
Copper	Cu					●	
Cyanide	Cn						
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow						●	
Fluoride	F					●	
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)						●	
Hydroxides	OH						
Iodine	I						
Iron	Fe					●	
Kjeldahl Nitrogen						●	
Lead	Pb					●	
Level				■			
Lithium	Li					●	
Magnesium	Mg					●	
Manganese	Mn					●	
Mercury	Hg					●	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					●	
Nickel	Ni					●	
Nitrate	NO_3					●	
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR					●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH					●	
Phenols						●	
PNA	PNA						►
Potassium	K					●	
Rubidium	RB						
Sediment Characterization							
Selenium	Se					●	
Scandium	SC						
Silica	SiO_2						
Silver	Ag					●	
Sodium	Na					●	
Solids, Dissolved	TDS					●	
Solids, Suspended	SOLS					●	
Strontium	Sr						
Surfactants							
Sulfate	SO_4					●	
Sulfide	SO_2						
Temperature (°C)							
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn					●	
Zirconium	Zr						
Radioactivity							
Gross Alpha (pci)						●	
Radium 226	Ra226					●	
Natural Uranium	U					●	
Gross Beta							
Cesium	Ce137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* C-b affiliated (DMP and WAP stations)

WY01	WY17	WY52	WY62
WY10	WY45	WY54	WY81
WY12	WY46	WY61	WY91

Revised 1/15/80.

Non-affiliated (Additional WAP stations)

TH75-5B	TH75-9B	TG71-3	Liberty Bell 12
TH75-13B	Equity Sulfur 1A	TG71-5	Getty 9-4D
Equity 1	CER RB-D-03	Oakland 3	TG71-[illegible]
TH75-18B	TH75-15B	GP-17X-8G	Equity 3S 13
TH75-10B	Greeno 4-4	Bu[illegible] 25	

SYMBOLS

- ● Applies to all C-b affiliated stations
- ► Applies to stations and species to [illegible] identified
- ■ Applies to both C-b affiliated and non-affiliated stations

1974–1975

STATION I.D.	COMPUTER CODE	1974 J	F	M	A	M	J	J	A	S	O	N	D	1975 J	F	M	A	M	J	J	A	S	O	N	D
QUALITY																									
CB-1	WY01											X					X						X		
CB-3	WY03																X								
SG-10	WY09																X						X		
SG-10R	WY10																								
SG-1-1	WY12																X						X		
SG-17-1R	WY17																								
SG-17-1	WY18											X					X						X		
AT-1C-1	WY45											X					X						X		
AT-1C-2	WY46											X					X						X		
SG-11-1	WY51																X						X		
SG-11-1R	WY52																						X		
SG-11-2	WY54																X						X		
SG-6-1	WY61																X						X		
SG-6-2	WY62																X								
SG-8	WY80											X					X						X		
SG-8R	WY81																								
SG-9-1	WY91																								
SG-10	WG10																								

1976–1977

STATION I.D.	COMPUTER CODE	1976 J	F	M	A	M	J	J	A	S	O	N	D	1977 J	F	M	A	M	J	J	A	S	O	N	D
QUALITY																									
CB-1	WY01										X													X	
CB-3	WY03																								
SG-10	WY09					X					X													X	
SG-10R	WY10																								
SG-1-1	WY12																								
SG-17-1R	WY17										X													X	
SG-17-1	WY18					X					X													X	
AT-1C-1	WY45					X					X														
AT-1C-2	WY46																								
SG-11-1	WY51										X														
SG-11-1R	WY52					X					X														
SG-11-2	WY54					X					X														
SG-6-1	WY61					X					X														
SG-6-2	WY62																							X	
SG-8	WY80					X					X														
SG-8R	WY81																								
SG-9-1	WY91					X					X														
SG-10	WG10					X					X													X	

1978–1979

STATION I.D.	COMPUTER CODE	1978 J	F	M	A	M	J	J	A	S	O	N	D	1979 J	F	M	A	M	J	J	A	S	O	N	D
QUALITY																									
CB-1	WY01					X						X						X							X
CB-3	WY03																								
SG-10	WY09					X						X						X							X
SG-10R	WY10																								
SG-1-1	WY12																								
SG-17-1R	WY17					X						X						X							X
SG-17-1	WY18											X						X							X
AT-1C-1	WY45					X						X						X							X
AT-1C-2	WY46																								
SG-11-1	WY51					X						X						X							X
SG-11-1R	WY52					X						X						X							X
SG-11-2	WY54																								
SG-6-1	WY61																								
SG-6-2	WY62																								
SG-8	WY80																	X							X
SG-8R	WY81																								
SG-9-1	WY91																								
SG-10	WG10					X						X						X							X

1980

STATION I.D.	COMPUTER CODE	1980 J	F	M	A	M	J	J	A	S	O	N	D
QUALITY													
CB-1	WY01						X						
CB-3	WY03												
SG-10	WY09												
SG-10R	WY10												
SG-1-1	WY12						X						
SG-17-1R	WY17												
SG-17-1	WY18												
AT-1C-1	WY45						X						
AT-1C-2	WY46						X						
SG-11-1	WY51												
SG-11-1R	WY52												
SG-11-2	WY54						X						
SG-6-1	WY61												
SG-6-2	WY62												
SG-8	WY80												
SG-8R	WY81						X						
SG-9-1	WY91						X						
SG-10	WG10												

FIGURE 5.3.5-1
LOWER TRACT AQUIFER WELLS
SAMPLING TIME INTERVALS
FOR QUALITY

5.3.5.3 Experimental Design

Water quality data from the Lower Aquifer wells were obtained to be used in the analysis for potential changes in water quality according to the methods discussed below.

5.3.5.4 Methods of Analysis

Methods used in analyzing water quality data from the Lower Aquifer wells were plots of the parameters with time for each well and a linear regression model to determine if linear trends in the data existed at the 0.05 level of significance.

5.3.5.5 Discussion and Results

Time series plots of all water quality parameters with respect to time are provided in the Appendix as Figures A5.3.5-1 through A5.3.5-8.

The greater than monthly sampling interval for Lower Aquifer wells precludes short-term analysis; only long-term analysis were performed.

The results of applying the linear regression model with respect to time are included in Tables 5.3.5-2 and 5.3.5-3. The four entries are as defined previously in 5.3.4.5 and are also described in the table. The omission of entries three and four indicates that no linear trend could be shown for the data at the 0.05 level of significance.

A long-term positive trend in boron concentration was indicated in WY81, but the slope of the linear regression line is nearly zero. Aluminum showed a negative trend although the slope is near zero. Magnesium showed negative trends at WY45 and WY51. Fluoride in WY01 and WY46 displayed a positive linear trend with regression line slopes of near zero.

5.3.6 Water Management: Impoundments/Land Application/Reinjection/Discharge

5.3.6.1 Scope

Temporary storages designated as Ponds A, B, and C are used for water from the mine during development. The impoundment system was described in detail in Volume 1 and briefly summarized in 5.2.6. The locations of the ponds were shown in Figure 5.2.6-1. Parameters and frequency of sampling under the permit requirements are shown in Table 5.3.6-1.

Water from the shafts may either be impounded in Ponds A and B, discharged from these ponds, applied to the soil through the sprinkler system, or reinjected. Reinjection testing was initiated by the end of 1980. Sprinkler irrigation and discharge under the permit were used during 1980.

TABLE 5.3.5-2
LONG TERM TIME TREND ANALYSIS OF WATER QUALITY IN LOWER AQUIFER WELLS

Dependent Variable		WY01	WY45	WY46	WY51	WY81
SPC (μmhos)	1.	4813.3750/8	1311.8750/8	1241.1250/8	38666.6667/3	1945.5714/7
	2.	0.1057	0.9490	0.4410	0.2982	0.4344
	3.					
	4.					
B (mg/l)	1.	1.6710/10	0.6756/9	0.6267/9	310.0000/3	0.5089/9
	2.	0.7570	0.6466	0.3400	0.7018	0.0007
	3.					0.0005
	4.					0.8234
Al (mg/l)	1.	0.2240/10	0.2267/9	0.1489/9	0.1733/3	0.2989/9
	2.	0.1759	0.0862	0.0327	0.4332	0.1045
	3.			-0.0002		
	4.			0.5017		
K (mg/l)	1.	5.7200/10	9.3111/9	3.9600/10	122.3333/3	1.5333/9
	2.	0.1034	0.8764	0.7386	0.6287	0.4655
	3.					
	4.					
TDS (mg/l)	1.	1807.7444/9	674.8800/10	610.1800/10		831.1000/8
	2.	0.8562	0.3187	0.3773		0.9331
	3.					
	4.					
Ca (mg/l)	1.	5.3900/10	4.9000/10	8.9200/10	9.3333/3	4.7778/9
	2.	0.1432	0.3637	0.1867	0.9648	0.2882
	3.					
	4.					
NH_3 (mg/l)	1.	2.6256/9	1.1222/9	0.9160/10		1.0833/9
	2.	0.1927	0.7237	0.8978		0.2143
	3.					
	4.					
Mg (mg/l)	1.	3.1700/10	3.0300/10	7.2000/10	9.3333/3	3.9444/9
	2.	0.1770	0.0090	0.0683	0.0380	0.2614
	3.		-0.0008		-0.0300	
	4.		0.5945		0.9964	
F (mg/l)	1.	27.7000/10	18.2000/10	16.6200/10	45.3333/3	20.9429/7
	2.	0.0316	0.0728	0.0262	0.0859	0.0508
	3.	0.0045		0.0003		
	4.	0.4579		0.4807		

NOTE: Entries in the table mean the following:
1. Mean/Number of paired observations
2. $\hat{\alpha}$ - to be compared with selected α (α = 0.05)
3. Slope - slope is units per month
4. r^2 value

TABLE 5.3.5-3

Summary of Long Term Linear Regression
Water Quality - Lower Aquifer

Parameter	Results
Specific Conductance	All but two wells show a negative trend: WY61 and WY62
Boron	One well shows a positive trend: WY81
Aluminum	Three wells show a negative trend: WY46, WY62, WY91
Potassium	One well shows a negative trend: WY52
Total Dissolved Solids	No linear trend
Calcium	No linear trend
Ammonia	Two wells show a negative trend: WY17, WY52
Magnesium	Two wells show a negative trend: WY45, WY51
Fluoride	Two wells show a positive trend: WY01, WY46

TABLE 5.3.6-1

WATER SAMPLING FREQUENCY REQUIREMENT
NPDES DISCHARGE POINT*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al		●			▲	
Ammonia	as NH_3		●				
Antimony							
Arsenic	As					▲	
Bacteria	SB						
Barium	Ba					▲	
Beryllium	Be					▲	
Bicarbonate	HCO_3					●	
Biological Oxygen Demand	BOD						
Bismuth	Bi					▲	
Boron	B		●			●	
Bromide	Br					●	
Cadmium	Cd					▲	
Calcium	Ca			●		●	
Carbonate	CO_3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl	●				●	
Chromium	Cr					▲	
Cobalt	Co					▲	
Coliform, Fecal							
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH					●	
Conductivity, Specific	SPC						
Copper	Cu			●		▲	
Cyanide	CN						
Dissolved Oxygen	DO					●	
Element Scan							
Fecal Streptococcus							
Flow		■					
Fluoride	F		●			●	
Gallium	Ga					▲	
Germanium	Ge					▲	
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe		●			▲	
Kjeldahl Nitrogen						▲	
Lead	Pb					▲	
Level							
Lithium	Li					▲	
Magnesium	Mg					●	
Manganese	Mn					▲	
Mercury	Hg			●		▲	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					▲	
Nickel	Ni					▲	
Nitrate	NO_3					●	
Nitrite	NO_2					●	
Odor						●	
Oil & Grease	OLGR	►	●			●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	PH	●					
Phenols			●			●	
PNA	PNA						
Potassium	K					▲	
Rubidium	Rb						
Sediment Characterization							
Selenium	Se					▲	
Scandium	SC						
Silica	SiO_2					●	
Silver	Ag			●			
Sodium	Na					▲	
Solids, Dissolved	TDS		●			▲	
Solids, Suspended	SOLS		●				
Strontium	Sr					▲	
Surfactants							
Sulfate	SO_4					●	
Sulfide	SO_2					●	
Temperature (°C)							
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti					▲	
Tungsten	W						
Turbidity							
Vanadium	V					▲	
Yttrium	Y						
Zinc	Zn			●		▲	
Zirconium	Zr					▲	
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					▼	
Natural Uranium	U					▼	
Gross Beta						●	
Cesium	Ce137					▼	
Sr90						▼	
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* NPDES discharge points:

001 S12T3S R97W
~600'S and 2100'E of section corner 1, 2, 11, 12

002 S12T3S R97W
~2100 'N and 3240'E of section corner 1, 2, 11, 12

003 S12T3S R97W
~2700'N and 4500'E of section corner 1, 2, 11, 12

SYMBOLS

● Applies to all NPDES discharge points
■ Daily flow also at USGS station WU61
▲ Total values
▼ Required if gross alpha or gross beta increases by 20% above average.
► Visual analysis of presence of oil and grease only.

Seepage monitoring is done by sampling wells WW12 and WW13. Locations of these wells are shown on Figure 5.2.6-1.

5.3.6.2 Objectives

Water quality is sampled at the Pond B discharge (WN40) to ensure compliance with the NPDES permit.

Wells WS12 and WW13 are sampled to determine the effects of seepage from Ponds A, B, and C on the water quality of the Uinta aquifer.

5.3.6.3 Experimental Design

Samples were obtained and analyzed according to the parameters and frequency shown in Table 5.3.6-1. The data from the analysis were then analyzed according to techniques discussed in 5.3.6.4.

5.3.6.4 Methods of Analysis

Data were analyzed by inspection of plots of the parameter concentrations with time, and by the application of a linear model as an initial screen for the existence of linear trends.

5.3.6.5 Discussion and Results

NPDES discharge of mine water is continuing in accord with requested permit criteria revision (letter submitted 10/19/80 to the Colorado WQCC) requiring change on the basis of an Agricultural stream use-classification for Piceance Creek. Meanwhile, the existing permit which would have expired December 31, 1980 has been temporarily extended for two years without change or response to C.B.'s requests to the WQCC for change. High values for fluoride have continued throughout 1980 and have been regularly reported to the Colorado WQCD. There have been no exceedances of recommended in-stream criteria for fish and wildlife.

Data from the analysis of weekly water quality samples required by the NPDES permit are shown in Table 5.3.6-2.

Results from the analysis of samples from monitoring wells WW12 and WW13 are shown in Tables 5.3.6-3 and 5.3.6-4, respectively. Table 5.3.6-5 is a comparison of means, ranges, and standard deviations of data from WW12 and WW13, to data from WW13 prior to the use of Pond C. The WW13 base data are based on only four samples.

Baseline concentrations exhibited considerable variation from sample to sample. The average of the four quality tests cannot be considered a standard for comparison of variation that may or may not be due to Tract activities. The range of variation within the undisturbed system was not established, however, these four tests are the best data currently available.

TABLE 5.3.6-2

CH-TRACT
NPDES WATER QUALITY SAMPLES
WEEKLY ANALYSIS

LOC	YR	MO	DY	FLOW (GPM)	TOTAL SUSPEND SOLIDS (MG/L)	TOTAL DISSOLVED SOLIDS (MG/L)	TOTAL F (MG/L)	TOTAL B (MG/L)	AMMONIA AS N (MG/L)	TOTAL PHENOL (MG/L)	AL (MG/L)	TOTAL FE (MG/L)	OIL AND GREASE (MG/L)	PH
WN40	80	2	24											8.80
			29	278.0	53.0	1000.0	10.00	.10	2.60	.004	.2	.08	8	9.40
		3	4		62.0	1100.0	9.80	-.10	3.10	.004	.4	.10	7	8.90
			12		160.0	1200.0	12.00	.10	2.40	.001	.3	.90	9	8.70
			13		103.0	1200.0	14.00	.10	2.00	-.001	.2	1.00	4	8.70
			21		220.0	1000.0	13.00	-.10	3.00	-.001	.5	4.00	3	7.60
			26		209.0	1200.0	13.00	-.10	2.40	-.001	.4	1.70	8	8.00
		4	2		292.0	1200.0	14.00	-.10	1.90	-.001	.5	2.00	-1	8.72
			9		132.0	1600.0	13.00	-.10	2.40	-.001	4.8	1.60	8	6.95
			17		95.0	1600.0	14.00	.20	1.70	.001	2.5	1.00	1	6.20
			24		53.0	1300.0	17.00	-.10	1.60	.007	2.9	.30	16	7.32
			28		222.0	1100.0	15.00	.60	1.50	.003	3.2	1.00	6	8.25
		5	7		150.0	1100.0	15.00	.60	1.50	.010	4.8	.90	1	8.85
			14		473.0	970.0	15.00	.40	1.70	.001	.4	1.30	7	7.70
			29		23.0	1000.0	13.00	.60	1.20	-.001	.1	.20	-1	7.97
		6	11	321.0	15.0	1300.0	18.00	.70	1.30	-.001	.1	.10	0	7.40
			18	148.0	24.0	1200.0	13.00	.70	2.00	-.012	.0	.08	1	8.40
			24	133.0	21.0	1200.0	16.00	.60	1.50	-.001	.3	.09	6	8.70
		7	3		17.0	1200.0	13.00	.60	1.80	-.001	.7	.04	5	6.90
			7		12.0	1200.0	19.00	.60	.40	-.001	.5	.10	8	7.50
			16		21.0	1200.0	17.00	.50	.80	.004	.3	.20	10	8.50
			23		24.0	1300.0	19.00	.50	-.04	-.001	.3	.30	10	8.00
		8	8		62.0	1400.0	18.00	.70	.50	-.001	.2	.10	5	8.40
			13		15.0	1500.0	19.00	.70	1.80	.002	.3	.10	4	7.50
			20		35.0	1500.0	18.00	.60	.90	.030	.3	.40	1	7.70
			27		10.0	1500.0	17.00	.60	1.00	.003	.2	.10	2	7.60
		9	2		31.0	1700.0	17.00	.70	.90	.003	1.0	.50	1	7.20
			10		24.0	1500.0	19.00	.80	1.30	.002	-.1	-.02	2	7.80
			17		18.0	1600.0	16.00	.70	.70	.002	.8	.20	1	7.40
			25		23.0	1600.0	18.00	.70	.70	-.001	1.0	.30	3	7.80
		10	2		58.0	1700.0	16.00	.40	.80	-.001	1.2	.40	2	7.50
			8		21.0	1500.0	15.00	.70	.90	-.001	.1	.10	1	8.30
			17		126.0	1700.0	17.00	.80	1.20	.008	1.7	1.80	11	6.90
			22		20.0	1400.0	20.00	.90	1.10	.005	.4	.30	5	8.20
			29		26.0	1700.0	16.00	.90	1.30	.004	.5	.30	1	8.60
		11	5		29.0	1600.0	21.00	.70	1.40	.001	1.3	.29	8	7.20
			12		8.0	1500.0	18.00	.70	1.50	.001	.3	.07	10	8.20
			21		579.0	1500.0	19.00	.70	.50	-.001	.4	1.80	5	7.10
			25		156.0	1500.0	19.00	.70	1.40	.001	.2	1.20	1	6.80

NOTE: - INDICATES LESS THAN

TABLE 5.3.6-3

Water Quality Data for Seepage Monitoring Well WW12

Indicator Variable	10/79	11/79	12/79	1/80	2/80	3/80	4/80	5/80	6/80	7/80	8/80	9/80	Average
Al	0.1			0.1	0.1	-	0.1	0.1	0.2	0.1	0.1	0.1	0.1
NH_3	0.2			11.0	6.1	14.0	13.0	13.0	13.0	9.4	8.9	9.5	9.8
As	0.02			0.02	0.02	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ba	0.5			0.5	0.5	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5
B	0.1			0.1	0.1	-	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Ca	*			14	15	-	29	13	15	16	12	14	
Cr	0.02			0.02	0.01	-	0.02	0.02	0.02	0.02	0.02	0.02	0.19
Cu	0.02			0.02	0.02	-	0.02	0.02	0.04	0.02	0.02	0.02	0.02
Fe	*			0.02	0.02	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pb	0.04			0.02	0.02	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Li	0.10			0.05	0.05	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mg	*			13	14	-	21	13	11	14	14	14	13
Mn	0.10			0.02	0.01	-	0.02	0.02	0.02	0.02	0.03	0.02	0.029
Mo	0.02			0.02	0.02	-	0.01	0.02	0.01	0.01	0.01	0.01	0.014
Ni	0.02			0.02	0.07	-	0.02	0.02	0.02	0.02	0.02	0.02	0.025
K	6.4			2.3	3.5	-	4.2	4.4	6.8	2.8	3.6	4.9	4.3
Ag	0.02			0.01	0.01	-	-	-	-	-	-	-	0.013
Na	170			120	120	-	130	120	130	120	120	130	128.9
Sr	*			1.6	1.0	-	1.1	0.6	0.8	1.4	1.9	1.8	1.3
Zn	0.5			0.02	0.01	-	0.01	0.01	0.02	0.02	0.02	0.02	0.07
Co	-			0.02	0.02	-	0.02	0.02	0.02	0.02	0.02	0.03	0.02
Se	-			0.02	-	-	-	-	-	-	-	-	0.002
Hg	0.0002			0.001	-	-	-	-	-	-	-	-	0.0006
BOD	30			1	2	17	18	25	24	21	15	39	19.2
COD	20			31	33	19	39	32	40	40	32	35	32.1
Hardness	*			88	95	-	160	86	83	75	88	93	96
Oil & Grease	4			12	1	5	11	16	4	5	6	9	7.3
Phenol	0.002			0.016	0.009	0.001	0.120	0.015	0.020	0.020	0.020	0.010	0.02
T. Alk.	*			90	90	90	110	98	100	110	110	110	100.9
TDS	*			500	520	530	550	520	560	530	490	530	526
Kj-N	-			12	14	14	16	15	14	12	13	12	14
DOC													-
HCO_3	*			68	1	1	18	1	1	1	96	1	21
CO_3	*			22	60	70	92	64	60	98	16	100	67
Br	0.1			0.1	0.4	0.1	-	0.1	0.1	0.1	0.1	0.1	0.13
Cl	1000			22	24	52	56	60	16	14	13	15	30
NO_3	7.2			50	27	0.1	0.1	0.1	0.5	0.5	0.5	0.5	8.65
SO_4	*			320	380	290	280	270	270	200	270	210	277
pH	-			-	-	9.2	9.1	-	9.3	9.0	9.1	8.9	9.1
DO	-			-	-	8	4.03	-	4.90	6.20	9.50	6.10	6.46
Cond	-			-	-	940	700	-	760	760	760	870	798
Temp	-			-	-	10	13.5	-	21.5	19	17	15	16
Depth (ft)	185.10	153.00	155.07	157.48	161.42	165.28	165.31	165.77	164.52	163.49	162.83	163.09	161.83
T. Alpha	-			-	-	-	-	-	-	-	-	-	-
T. Beta	-			-	-	-	-	-	-	-	-	-	-
F	3.0			0.9	1.0	0.8	0.7	0.6	1.3	0.4	1.3	1.1	1.11

TABLE 5.3.6-4

Water Quality Data for Seepage Monitoring Well WW13

Indicator Variable	10/79	11/79	12/79	1/80	2/80	3/80	4/80	5/80	6/80	7/80	8/80	9/80	Average
Al		-	0.1	0.1	0.1	-	0.1	0.1	0.1	0.1	-	-	0.1
NH_3		-	0.04	0.20	0.3	2.10	0.50	0.3	0.20	0.30	0.03	0.06	0.56
As		-	0.03	0.02	0.02	-	0.02	0.02	0.02	0.02	-	-	0.021
Ba		-	0.5	0.5	0.5	-	0.5	0.02	0.5	0.5	-	-	0.5
B		-	0.1	0.2	0.1	-	0.1	0.5	0.1	0.1	-	-	0.11
Ca		-	55	48	60	62	85	59	5.7	67	65	75	58.52
Cr		-	0.02	0.02	0.02	-	0.02	0.02	0.02	0.02	-	-	0.02
Cu		-	0.02	0.02	0.01	-	0.02	0.02	0.02	0.02	-	-	0.19
Fe		-	0.02	0.02	0.06	-	0.02	0.02	0.08	0.02	-	-	0.03
Pb		-	0.05	0.02	0.02	-	0.02	0.02	0.02	0.02	-	-	0.02
Li		-	0.05	0.05	0.05	-	0.05	0.05	0.05	0.05	-	-	0.05
Mg		-	64	66	67	72	72	70	64	69	70	67	68.4
Mn		-	0.04	0.04	0.07	-	0.10	0.08	0.06	0.10	-	-	0.07
Moly		-	0.10	0.07	0.06	0.05	0.03	0.04	0.04	0.03	0.04	0.06	0.05
Ni		-	0.02	0.02	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K		-	1.9	2.1	3.2	2.2	3.2	3.6	4.2	1.7	2.2	3.9	2.75
Ag		0.01	0.02	0.01	0.01	-	-	-	-	-	-	-	0.03
Na		-	170	180	180	180	190	180	180	180	180	190	181
Sr		-	6.4	6.6	3.8	-	4.9	2.3	3.9	5.7	-	-	4.87
Zn		-	0.05	0.06	0.06	-	0.04	0.02	0.02	0.02	-	-	0.04
Co		0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
Se		0.020	-	0.002	-	-	-	-	-	-	-	-	0.01
Hg		0.020	-	0.001	-	-	-	-	-	-	-	-	0.01
BOD		-	1.4	31	1	24	78	20	1	35	6	19	21.8
COD		-	7	2	11	28	3	1	24	16	14	8	13
Hardness		-	400	390	430	-	-	440	280	450	450	460	413
Oil & Grease		-	3	3	1	3	1	14	10	1	4	1	4
Phenol		-	0.001	0.020	0.010	0.001	0.010	0.030	0.030	0.004	0.007	0.003	0.01
T. Alk.		-	370	380	380	415	430	390	420	400	420	430	405
TDS		-	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Kj-N		-	0.4	1.6	45	2	0.7	0.4	0.3	0.6	0.1	0.3	4.9
DOC		48	-	23	10	3	2	10	7.4	12	1	2	17
HCO_3		-	370.0	380	380	335	430	370	420	400	420	430	388.2
CO_3		-	1.0	1.0	1	80	1	20	1	1	1	1	17.1
Br		-	0.1	0.1	0.1	-	-	0.1	0.1	0.1	-	-	0.10
Cl		-	7	16	20	30	47	81	9.5	9	6.8	9.9	24.11
NO_3		-	26	28	89	35	3.9	0.1	0.5	0.5	0.5	0.5	19.91
SO_4		-	590	500	480	400	420	400	350	320	410	400	425
pH		-	7.8	-	-	7.6	7.3	8.27	7.4	7.5	7.3	7.1	7.5
DO		-	4.5	-	-	6.7	4.7	4.8	4.5	7.2	8.8	4.4	5.7
Cond		-	800	-	-	1380	1200	1590	1400	1290	1280	1440	1298
Temp		-	12.5	-	-	11	15	12	24.2	20	17	18	16.2
Depth (ft)		377.43	375.85	373.35	373.35	375.18	373.46	373.20	372.85	371.95	368.09	361.80	372.00
T. Alpha		29	-	-	-	-	-	-	-	-	-	-	29
T. Beta		30	-	-	-	-	-	-	-	-	-	-	30
F		-	0.1	0.1	0.2	-	0.2	0.1	0.5	0.1	-	-	0.19

TABLE 3.5.6-5

Comparison of Data From WW12 and WW13 to Data From WW13 Before Pond C Was Used

	Baseline (WW 13 prior to filling Pond C - 1979 Annual Report Vol II, PG 114)			Water Year 1980 WW 12			Water Year 1980 WW 13		
	Mean	Range	Stand. Devia.	Mean	Range	Stand. Devia.	Mean	Range	Stand. Devia.
Conductivity	1200	600	270.8	813	240	75	1327	790	215.5
SO_4	500	164	66.8	308	400	105	430.8	270	74.6
Ca	57	15	6.6	22.7	89	26.1	59	79	19.7
TDS	1250	1000	500	630.8	1060	296.6	998	20	5.8
Alk	368	40	18.9	159	510	149	405.8	60	21.9
NH_3	0.25	0.50	0.21	9.6	13.8	4.3	0.5	2.9	0.8
CO_3	10	37	18.5	64.3	101	35.1	14.3	81	31.3
HCO_3	357	80	38.6	81.3	601	174.5	390.8	110	35
B	0.13	0.1	0.05	0	0.3	0.1	0.05	0.29	0.13
F	0.15	0.1	0.06	1.1	2.6	0.7	0.16	0.59	0.17
Na	178	10	5	132.7	60	21.5	181.7	20	5.8
Coef. TDS/Conductivity	1.07	0.83	0.4	0.6	0.3	0.1	0.8	0.6	0.257

In WW12, parameters which had significantly higher concentrations than 1979 WW13 baseline averages were ammonia (38 times higher), carbonate (6.4 times higher), and fluoride (17 times higher). These large differences may be due to local background conditions. Compared to the 1979 WW12 figures, ammonia was 2.2 times higher and carbonate was 1.4 times higher in 1980. Fluoride was lower, 1.1 mg/l in 1980 vs. 1.4 in 1979. Average concentrations of all the selected parameters except ammonia, carbonate, and fluroide in WW12 were less than in the WW13 baseline. Several of the parameters, especially bicarbonate, were considerably less. Average concentration of all the selected parameters except ammonia and carbonate decreased in WW12 from the previous year. In WW12, decreasing linear trends occurred for Total Dissolved Solids, sodium, sulfate, total alkalinity, and bicarbonate. No positive linear trends occurred despite the average increases from the previous year in ammonia and carbonate. In WW13, parameters which significantly increased in concentration from baseline were conductivity, total alkalinity, ammonia, carbonate, and bicarbonate. Of these, ammonia doubled concentration from 0.25 mg/l to 0.5 mg/l, the others increased less than 14 percent. Average concentrations of all the other selected parameters decreased or remained at the same levels as the previous year. Linear regression analysis revealed increasing linear trends for fluoride, calcium, and the ratio of total dissolved solids to specific conductance despite little change in the average concentration from the previous year. No decreasing linear trends were noted. Decreased average values of many parameters and decreasing linear trends in WW12 indicate that some changes in water quality may be resulting from pond seepage.

5.3.7 Shaft and Mine Water

5.3.7.1 Scope

Sampling and analysis of the quality of water from the shafts were done throughout shaft development. The analysis provides background information should further analysis or investigation be necessary or if high readings occur in the discharges. Analysis may help in forecasting water quality in the level development mining and provide guidance for water management planning. Parameters measured in the V/E Shaft are shown in Table 5.3.7-1.

5.3.7.2 Objectives

The objectives in shaft sampling are to obtain information on the changes in water quality as the shafts are sunk in order to increase knowledge and understanding of the subsurface hydrology.

5.3.7.3 Experimental Design

Samples are obtained from the probe holes prior to any grouting activity. Weekly sump samples are obtained to analyze mine water before commingling. Monthly reports of shaft water quality are sent to the Oil Shale Office.

TABLE 5.3.7-1

Water Quality Parameters Analyzed in V/E Shaft Probe Holes

Aluminum	Bicarbonate	Ammonia - Nitrate
Arsenic	Carbonate	Oil and Grease
Boron	Chloride	
Calcium	Fluoride	
Iron	Nitrate	Phenols
Lead	Sulfate	Dissolved Oxygen
Magnesium	Total Alkalinity	
Manganese	Total Suspended Solids	
Molybdenum		
Potassium		
Sodium		

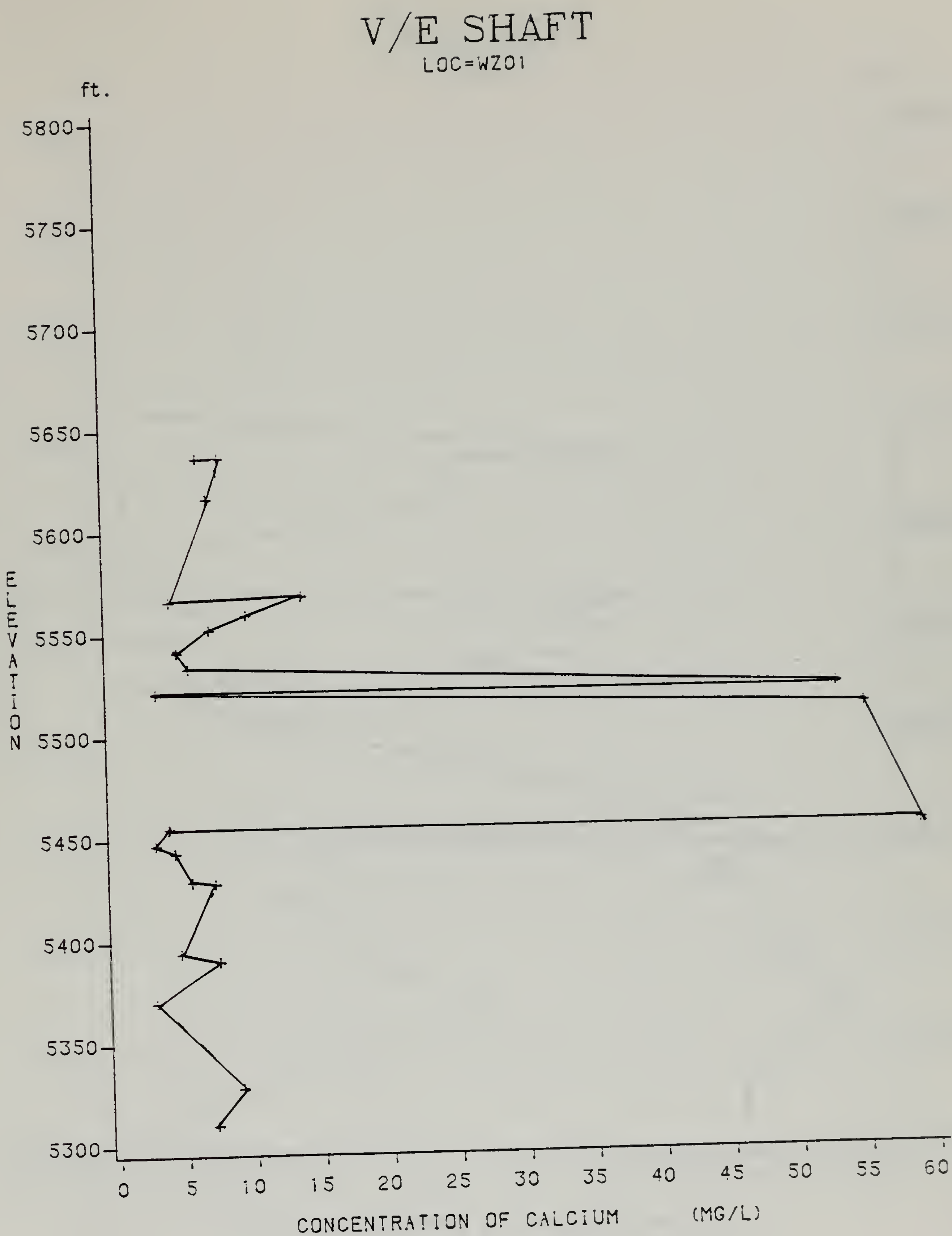


FIGURE 5.3.7-1
Water Quality Parameters

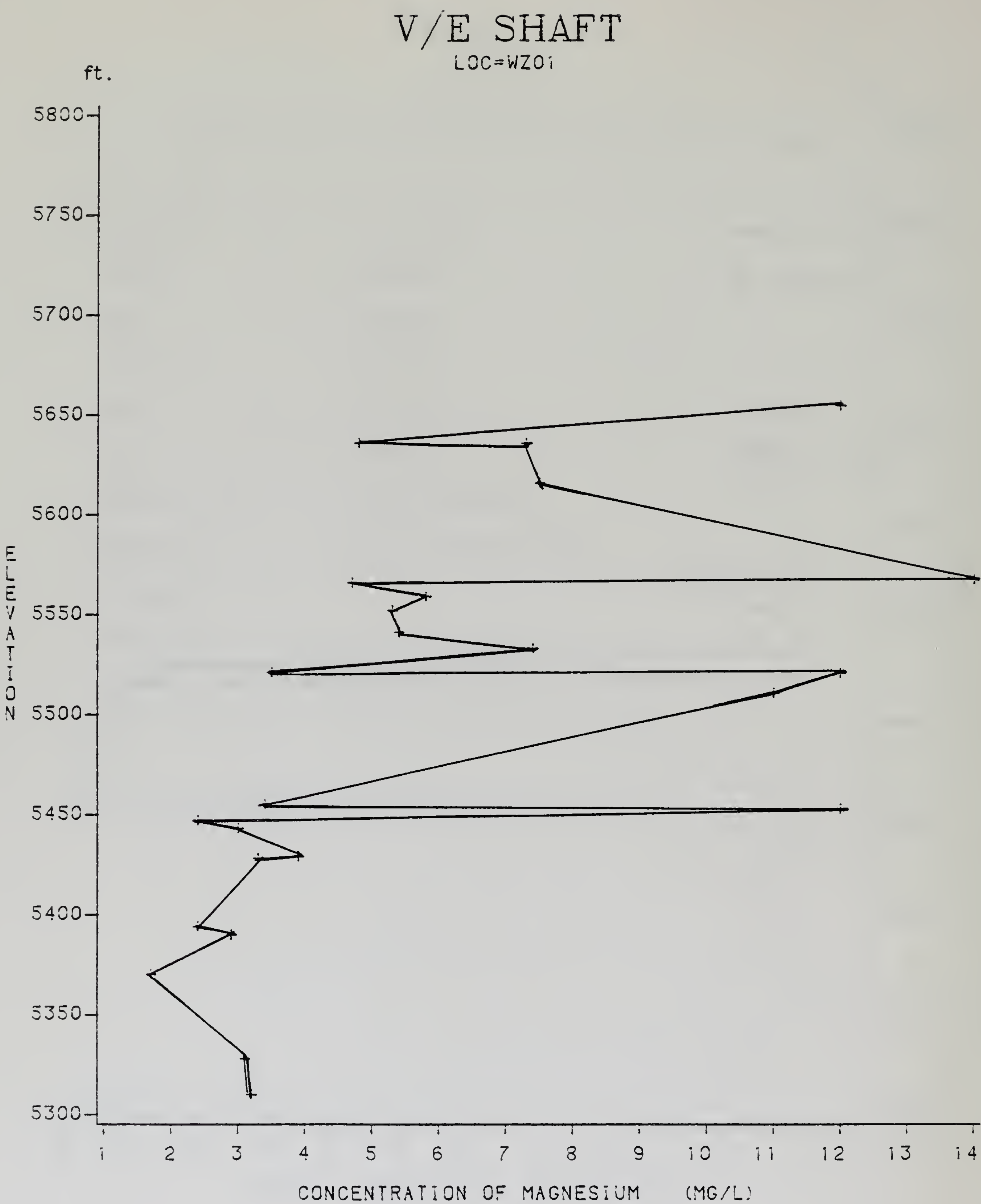


FIGURE 5.3.7-2
Water Quality Parameters

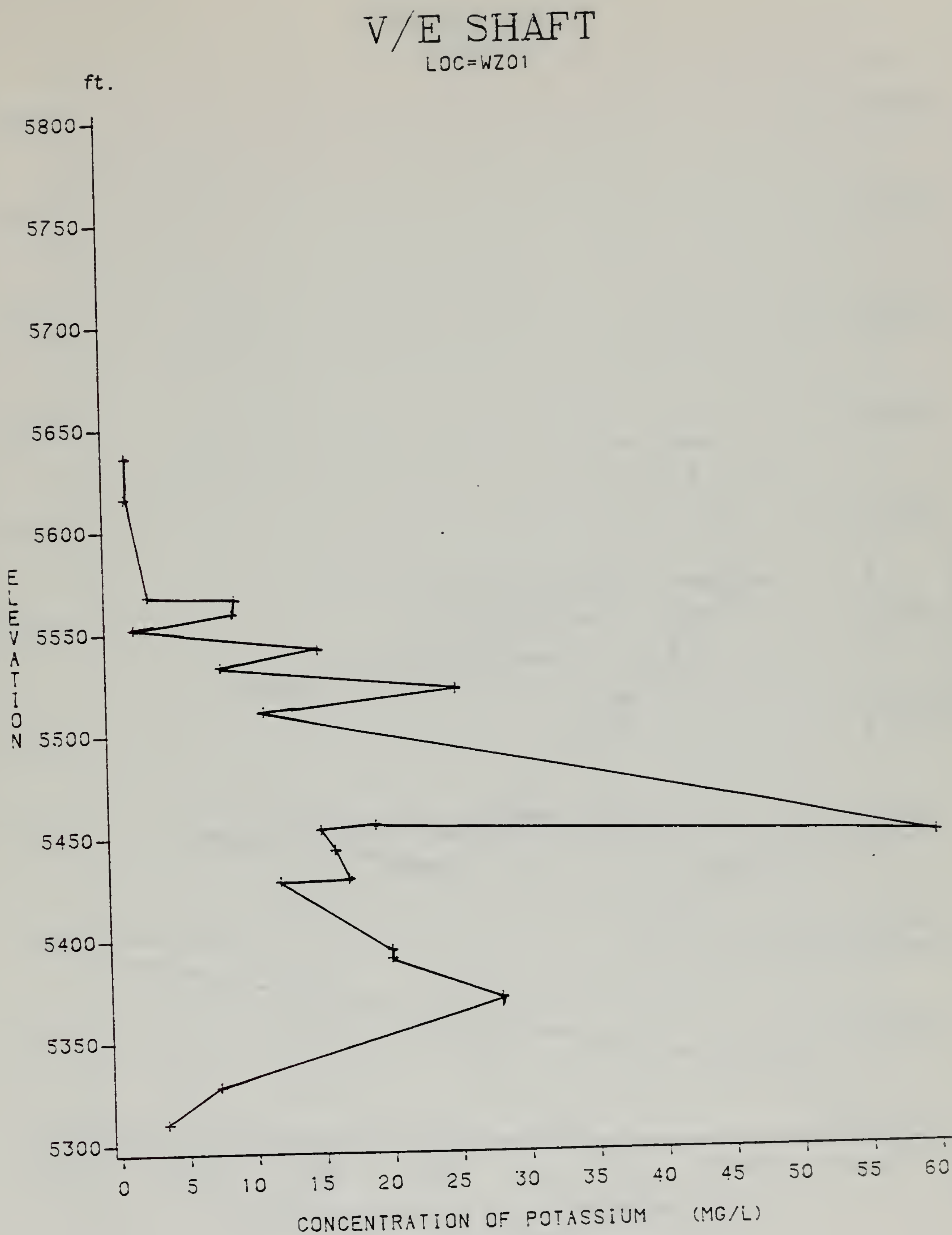


FIGURE 5.3.7-3
Water Quality Parameters

V/E SHAFT

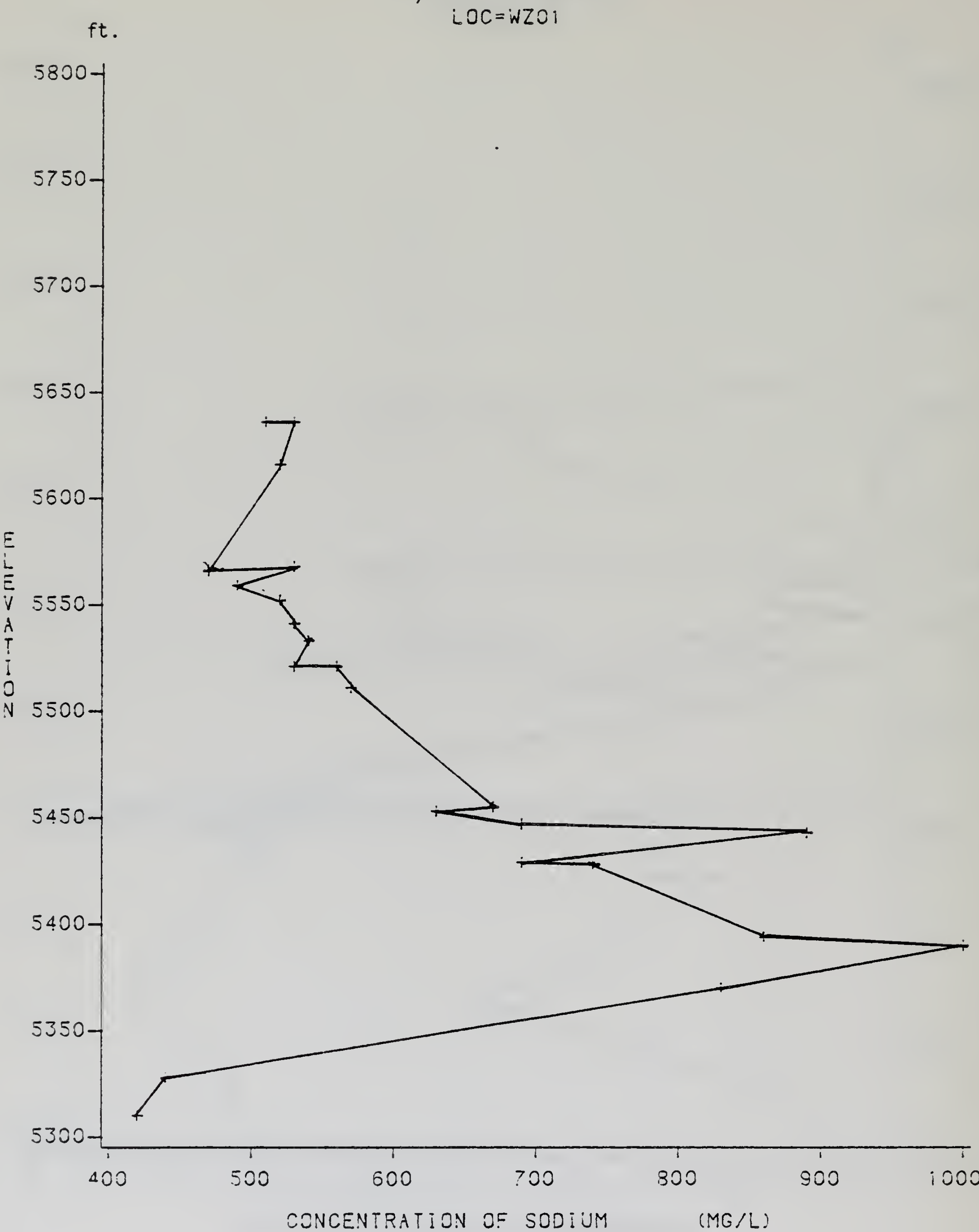


FIGURE 5.3.7-4

Water Quality Parameters

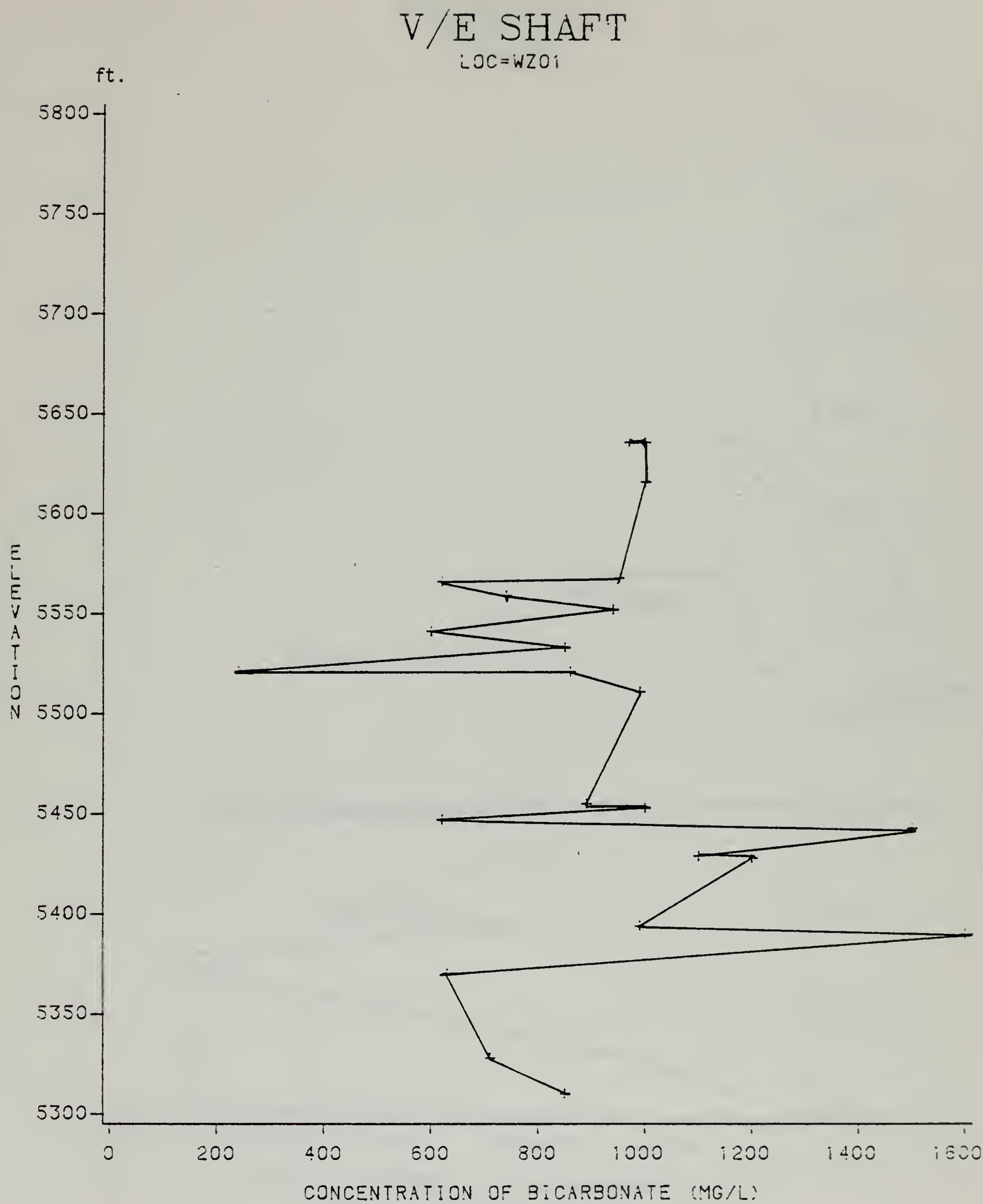


FIGURE 5.3.7-5
Water Quality Parameters

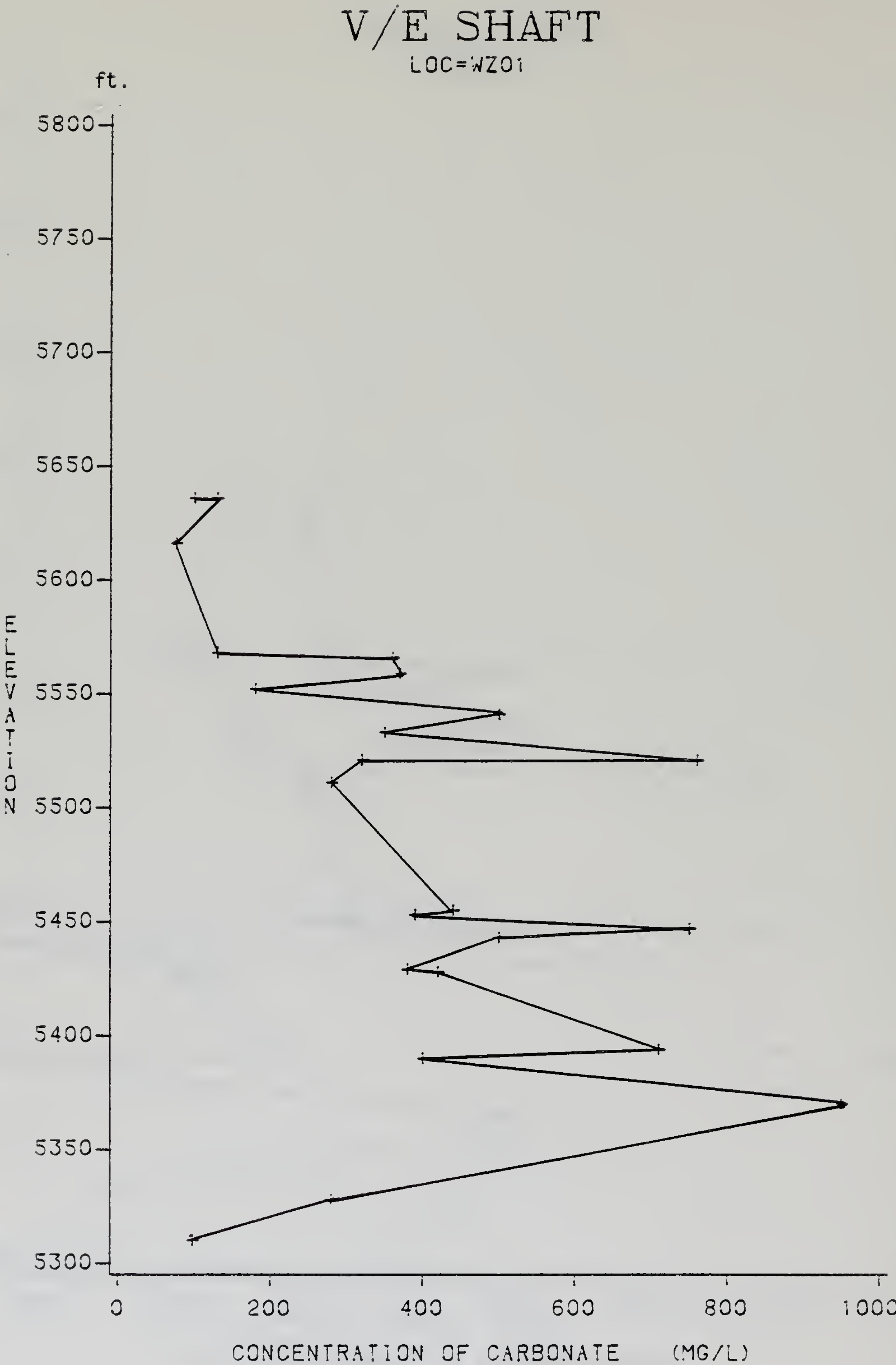


FIGURE 5.3.7-6
Water Quality Parameters

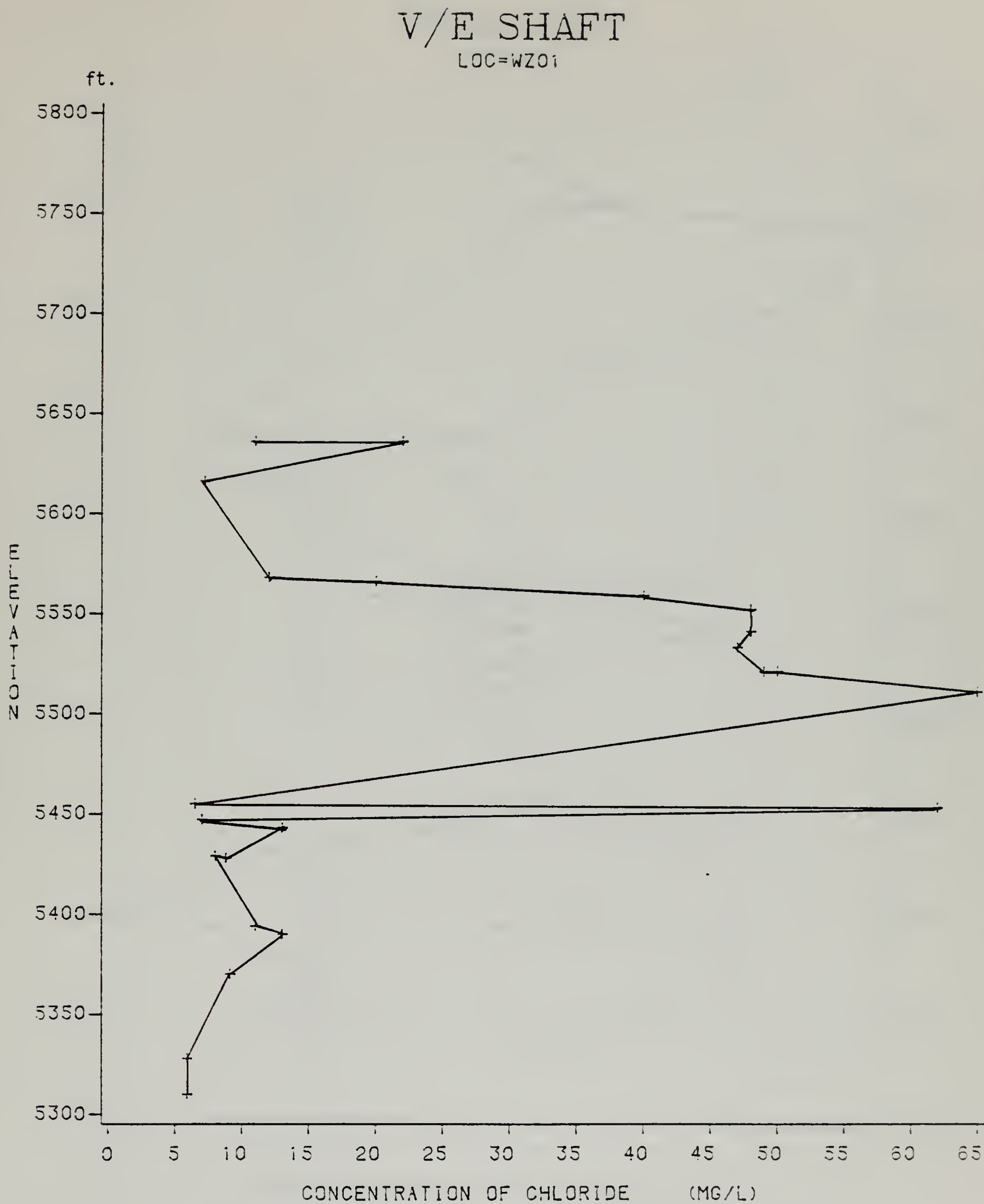


FIGURE 5.3.7-7
Water Quality Parameters

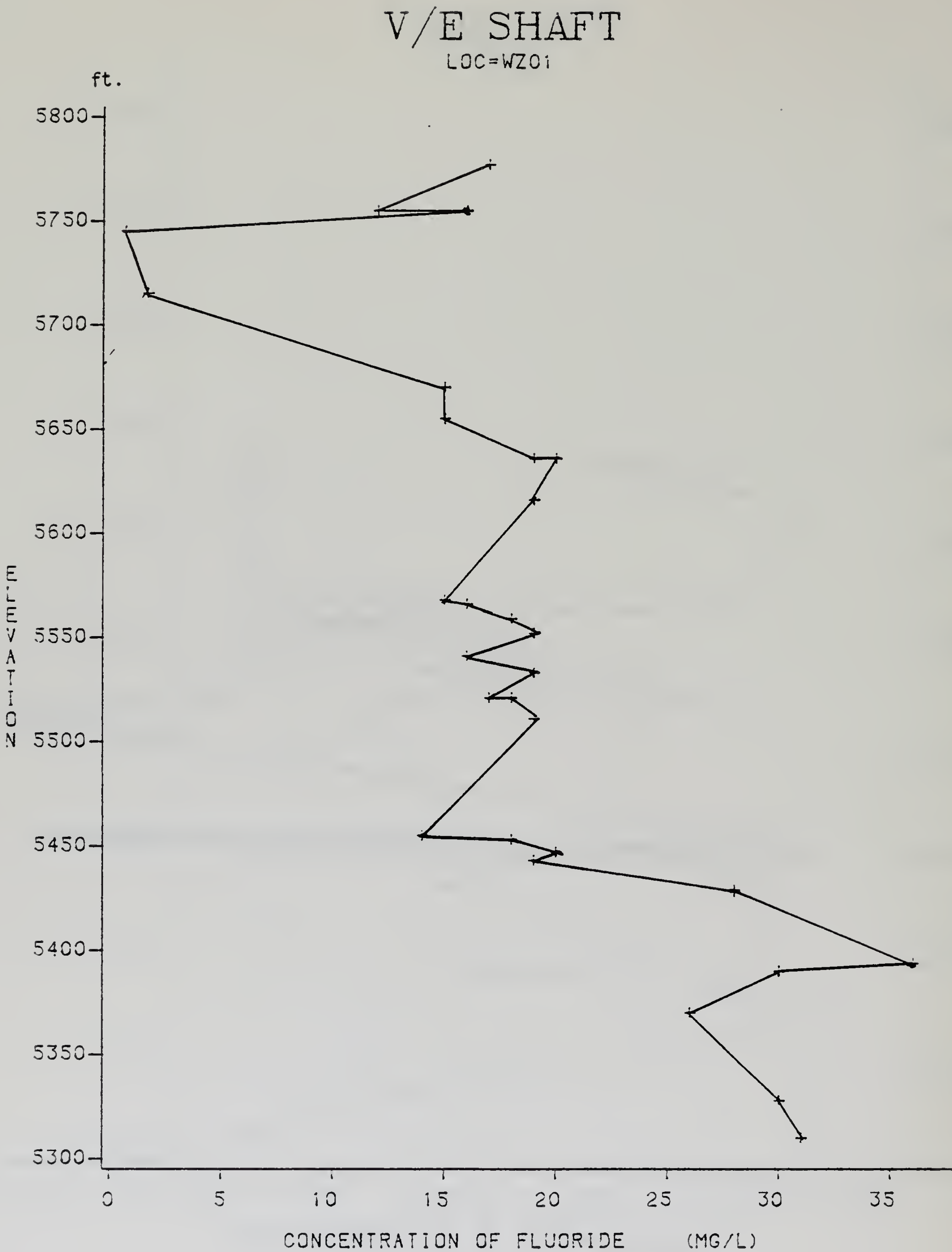


FIGURE 5.3.7-8
Water Quality Parameters

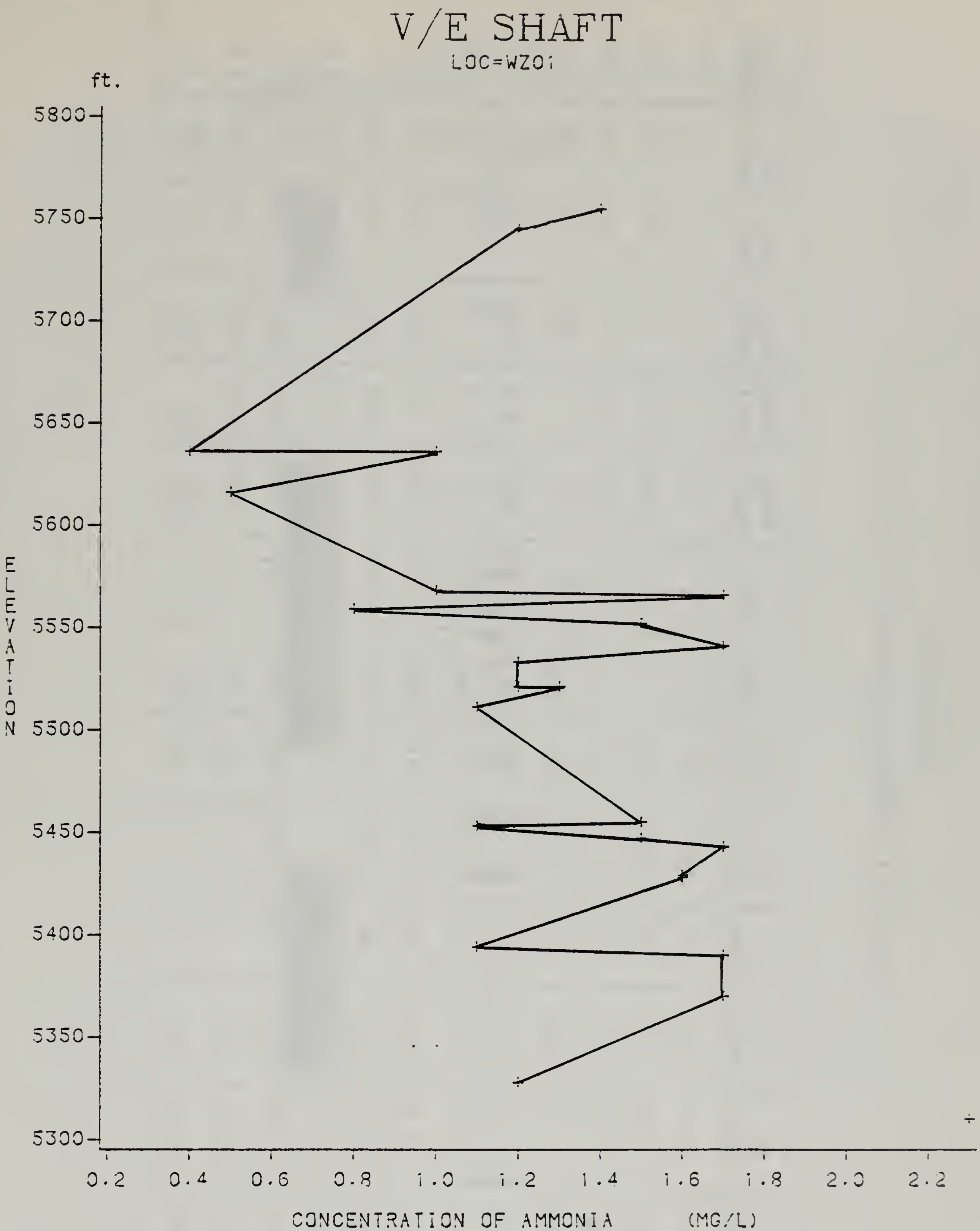


FIGURE 5.3.7-9
Water Quality Parameters

TABLE 5.3.7-2

Water Quality Parameters with Depth in the V/E Shaft

DEPTH (V/E)	Na (mg/l)	Na (meq)	Ca (mg/l)	Ca (meq)	Mg (mg/l)	Mg (meq)	Cl (mg/l)	Cl (meq)	HCO_3 (mg/l)	HCO_3 (meq)	SO_4 (mg/l)	SO_4 (meq)	CO_3 (mg/l)	CO_3 (meq)
5636	510	22.2	6.5	.08	4.8	.10	22	.62	970	9.7	24	.12	130	2.6
5616	520	22.6	7.2	.09	7.5	.15	7.2	.20	1000	10.0	8	.04	76	1.5
5568	530	23.0	14	.17	14.	.28	12	.34	950	9.5	77	.41	130	2.6
5559	490	21.3	9.9	.12	5.8	.12	40	1.1	740	7.4	81	.43	370	7.4
5556	470	20.4	4.3	.05	4.7	.10	20	.56	620	6.2	110	.59	360	7.2
5552	520	22.6	7.2	.09	5.3	.11	48	1.35	940	9.4	5	03	180	3.6
5541	530	23.0	4.8	.06	5.4	.11	48	1.35	600	6.0	110	.59	500	10
5533	540	23.5	5.6	.07	7.4	.15	47	1.32	850	8.5	49	.26	350	7
(1) 5521	560	24.3	53	.66	12	.25	49	1.38	860	8.6	110	.59	320	6.4
(2) 5521	530	23.0	3.2	.04	3.5	.07	50	1.40	240	2.4	200	1.06	760	15.2
5511	570	24.8	55	.68	11	.23	65	1.83	990	9.9	64	.34	280	5.6
5453	630	27.4	59	.74	12	.25	62	1.7	1000	10	180	1.0	390	7.9

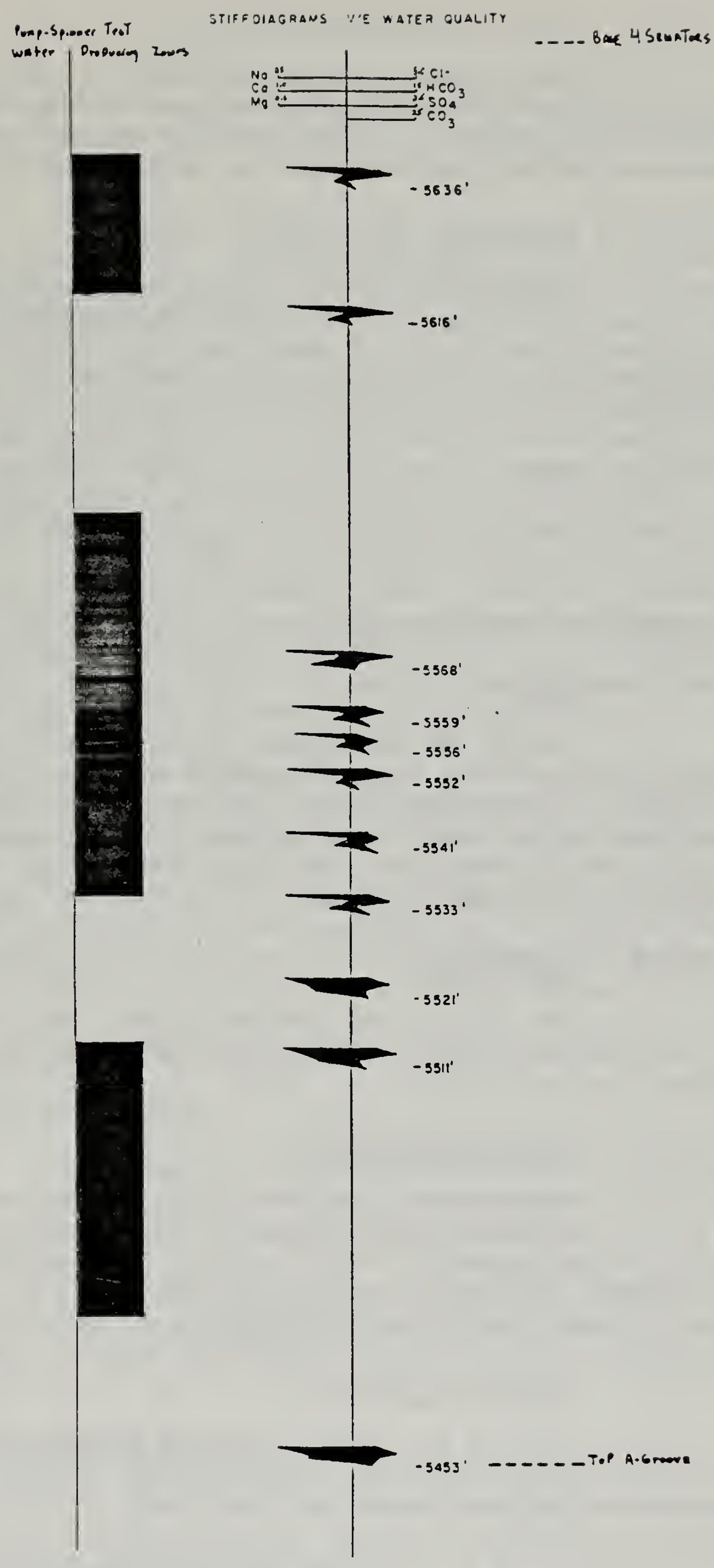


FIGURE 5.3.7-10

Stiff Diagram for Selected Ions with Respect to Elevation in the V/E Shaft

5.3.7.4 Method of Analysis

Water quality parameters shown in Table 5.3.7-1 were plotted with respect to depth for qualitative analysis. In addition, units of some variables were converted from milligrams per liter to milliequivalents per liter and plotted on a Stiff diagram for qualitative analysis.

5.3.7.5 Discussion and Results

The plots of water quality parameters with respect to elevation in the V/E Shaft are shown in Figures 5.3.7-1 through 5.3.7-9. The units of variables shown on Table 5.3.7-2 were converted from milligrams per liter to milliequivalents per liter and plotted in the form of the Stiff diagram shown as Figure 5.3.7-10.

5.3.8 Process Water

No retort process waters exist since no retorting has commenced.

5.3.9 Mined Rock Dumps and Stockpiles

5.3.9.1 Scope

During the development phase, several dumps and stockpiles will be created on the Tract. Major stockpile areas are shown in Figure 6.1 of Volume 1. Pollution of surface water resources can be caused by storm runoff from these piles. Storm runoff may not only dissolve salts encrusted on the surface of these piles, but may also carry particles to the stream sediment. The particles may carry associated pollutants.

5.3.9.2 Objectives

The analysis of samples of water and sediment collected over time will provide data needed to determine the pollution potential of runoff from the dumps and stockpiles.

5.3.9.3 Experimental Design

Sediments in the water courses were sampled and analyzed by the EPA during baseline at USGS gauging stations along Piceance Creek, and in shallow wells in the immediate Tract vicinity. A leaching study was done for new oil shale rock in the region. A site-specific study at C-b has just been inititated and is discussed in Section 8.11.2.1.

5.3.9.4 Method of Analysis

Data of the 1979 study were analyzed subjectively by comparison with leaching characteristics of other shales in the region. Those for the new study are not yet available.

5.3.9.5 Discussion and Results

Table 5.3.9-1 is a summary of the 1979 results of EPA Grant No. R806278-01-1 Leaching Characteristics of Raw Surface Stored Oil Shale. In that study, the leaching characteristics of stored oil shale from C-b were compared with those characteristics of oil shales from other areas.

Constituents in the shale with high fractions included calcium, potassium, and sodium. Leaching characteristics also showed no fraction of chloride, carbonate, fluoride, iron, bicarbonate, lithium, nitrate, tin, sulfate, or zinc from C-a composite or C-a R-5 and Mahogany shales.

The hazardous waste regulations promulgated under the Resource Conservation and Recovery Act (RCRA) require persons generating solid wastes to assesy the hazardousness of those wastes and to notify EPA of any activities involving the wastes. Also, persons who treat, store or dispose of hazardous wastes must obtain EPA approval for those activities.

In compliance with these requirements, Cathedral Bluffs notified EPA on August 15, 1980 of their status as a generator of a hazardous waste, specifically waste oil. Because the hazardous waste activity at the site is limited to generation, no EPA approval is required. Also, because the waste oil is recycled, it is substantially exempt from regulation, such as limitations on on-site storage prior to recycling.

The Toxic Substances Control Act (TSCA) regulates all aspects of manufacturing and use of chemical substances. Implementation of TSCA began with development of an inventory of all chemical substances produced in commerce. Occidental, on April 26, 1978, registered shale oil on the TSCA inventory. Although the registration was based on shale oil produced at Occidental's Logan Wash facility, because shale oil is on the inventory, any person may produce shale oil from any facility without EPA approval. Therefore, Cathedral Bluffs has no TSCA-related restrictions on production of shale oil.

5.3.10 Sediment Characterization

5.3.10.1 Scope

Samples of streambed sediments in all the major drainages on and around C-b Tract and along Piceance Creek were collected and analyzed for major chemical constituents during baseline.

Under a provision of the Environmental Lease Stipulations, as modified by conditions of approval, a sample of streambed sediment was taken near Station 09306042 (WU42) prior to initiation of discharge into Piceance Creek.

5.3.10.2 Objectives

The objectives of the sediment characterization program are to determine through chemical analysis the baseline composition of streambed sediment, and to determine the sorptive which might be present in water discharged into a particular stream.

TABLE 5.3.9-1

SUMMARY OF RESULTS AS OF OCTOBER 21, 1979 - EPA GRANT NO. R806278-01-1

LEACHING CHARACTERISTICS OF RAW SURFACE STORED OIL SHALE

		COLONY SOIL		C-b SOIL		COLONY RAW SHALE		COLONY WEATHERED		HORSE DRAW SALINE		UNION NAT. RETORTED		C-a COMPOSITE		C-a R-5 & Maho.	
	Units	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV	Initial	~3 PV
Al	mg/l	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.85	0.80	<0.05	<0.05	<0.05	<0.05	0.70	0.30
As	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
B	mg/l	0.70	0.53	0.65	0.87	0.75	0.43	0.365	0.170	29.5	0.95	0.170	0.210	1.45	0.40	0.59	<0.025
Ba	mg/l	0.40	0.12	0.169	0.038	0.34	0.16	0.495	0.088	0.17	0.10	0.120	0.037	0.093	0.051	0.11	0.088
Be	mg/l	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Ca	mg/l	960.0	200.0	330.0	6.5	1110.0	200.0	500.0	25.0	520.0	220.0	45.0	13.0	425.0	100.0	1430.0	900.0
Cl	mg/l	200.0	1.4	0.0	0.0	22.0	3.0	71.0	1.5	430.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
CO_3	mg/l	0.17	1.04	0.0	0.0	0.18	1.2	0.12	0.63	0.10	0.15	0.0	0.0	0.0	0.0	0.0	0.0
Cr	mg/l	<0.025	<0.025	0.069	<0.025	<0.025	<0.025	<0.025	<0.025	0.55	<0.025	0.100	0.031	<0.025	<0.025	<0.025	<0.025
Cu	mg/l	0.33	0.075	0.28	<0.025	0.16	<0.025	0.31	0.05	0.22	<0.025	0.160	<0.025	0.060	<0.025	0.16	<0.025
EC	µmhos/cm @25°C	9000.0	2000.0	3300.0	750.0	527.0	106.0	537.0	48.0	11000.0	1100.0	1100.0	385.0	6500.0	750.0	15,000.0	2750.0
F	mg/l	10.0	1.4	0.0	0.0	7.2	5.0	5.2	8.7	75.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.01	0.18	0.0	0.0	<0.03	<0.03	<0.03	<0.07	0.75	0.01	0.0	0.0	0.0	0.0	0.0	0.0
HCO_3	mg/l	233.0	192.0	0.0	0.0	304.0	250.0	233.0	189.0	243.0	122.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K	mg/l	270.0	50.0	22.0	1.3	19.0	2.3	57.0	0.8	19.0	2.0	55.0	11.0	34.0	2.0	280.0	50.0
Li	mg/l	0.47	0.09	0.0	0.0	0.085	0.10	0.012	<0.004	2.4	0.11	0.0	0.0	0.0	0.0	0.0	0.0
Mg	mg/l	1450.0	140.0	145.0	2.6	72.0	18.0	365.0	17.0	1050.0	12.2	103.0	60.0	415.0	48.0	0.0	0.0
Mn	mg/l	0.10	0.38	0.075	<0.025	0.240	0.820	0.07	0.068	2.9	0.23	0.05	<0.05	0.240	0.062	0.35	<0.05
Mo	mg/l	0.84	0.18	0.125	<0.05	0.07	0.18	0.74	0.11	0.44	0.09	0.32	0.125	2.20	0.475	6.20	0.225
Na	mg/l	340.0	6.2	2050.0	210.0	100.0	15.0	350.0	33.0	1430.0	65.0	44.0	16.0	740.0	33.0	3600.0	310.0
Ni	mg/l	0.060	0.040	0.075	<0.05	0.087	<0.05	0.06	<0.05	0.48	0.04	<0.05	<0.05	0.090	<0.05	0.085	<0.05
NO_3	mg/l	1800.0	<0.2	0.0	0.0	25.0	<2.5	245.0	0.8	<25.0	<6.25	0.0	0.0	0.0	0.0	0.0	0.0
Pb	mg/l	0.27	0.20	0.31	0.070	0.17	0.095	0.22	0.13	0.57	0.080	0.10	0.105	0.204	0.075	0.150	<0.05
pH	----	7.1	8.0	8.3	8.8	7.8	7.9	8.1	8.3	6.8	7.3	8.6	8.3	8.2	8.3	11.4	12.0
Se	mg/l	<0.01	<0.01	<0.0005	<0.0005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	mg/l	7.3	8.0	11.0	11.7	7.61	4.54	14.7	6.78	7.5	3.4	11.0	12.0	10.0	10.9	5.94	1.65
Sn	mg/l	1.37	0.25	0.0	0.0	0.24	0.17	0.67	0.047	1.1	0.38	0.0	0.0	0.0	0.0	0.0	0.0
SO_4	mg/l	4200.0	1000.0	0.0	0.0	4250.0	400.0	2650.0	33.0	5600.0	425.0	0.0	0.0	0.0	0.0	0.0	0.0
TDS	mg/l	19,800.0	1850.0	0.0	0.0	6000.0	770.0	4760.0	220.0	12,600.0	1300.0	0.0	0.0	0.0	0.0	0.0	0.0
TOC	mg/l	512.0	44.0	0.0	0.0	0.0	0.0	0.0	0.0	228.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	mg/l	0.65	0.02	0.0	0.0	0.62	0.06	0.11	0.24	5.2	0.39	0.0	0.0	0.0	0.0	0.0	0.0

Colony Soil - - - - - - - - Approximately 500 yards north of mine portal
C-b Soil - - - - - - - - - Cottonwood Gulch SE of plant
Colony Raw Shale - - - - - mine stock pile below surface
Colony Weathered - - - - - 400 yards SW of mine portal, tallus slope material
Horse Draw - - - - - - - - Saline zone
Union Naturally Retorted - 90 yards SW of mine portal
C-a Composite - - - - - - - Composite of raised bore cuttings from the G-level in the R-5 zone to surface. Includes some overburden that is not shale
C-a R-5 & Mahogany - - - - Composite of materials from the R-5 and Mahogany zones

Note: All data in this table were obtained by leaching columns 106 cm in length under saturated conditions with de-ionized water. All concentration data in milligrams per liter.

5.3.10.3 Experimental Design

One composite sample for particle size, chemical composition, and mineral analysis was taken prior to initiation of discharge operations from Station WU42. No subsequent samples have been taken. Discharges are rigorously monitored under conditions of the NPDES permit.

5.3.10.4 Method of Analysis

Particle size distribution and mineral composition data were tabulated for subjective analysis.

5.3.10.5 Discussion and Results

Table 5.3.10-1 shows the results of the sediment characterization analysis. As shown in the table, high percentages exist for silicon and aluminum. Lesser fractions are shown for organic material, iron oxide, calcium, sodium, potassium, and iron. Small fractions of magnesium and titanium are also shown.

Analysis of trace elements showed manganese and phosphorus to have the highest concentrations; both were less than 1000 ppm. Fluoride concentration was 330 ppm and barium was 240 ppm. The remaining trace element concentrations were less than 100 ppm.

TABLE 5.3.10-1

Sediment Characterization Analysis

Particle Size Analysis

Percent Passing (mm sieve and hydrometer)

1 mm	100
0.5	88
0.25	78
0.1	39
0.05	18
0.002	2

Percent

Organic Materials	2.8
Fe_2O_3	1.5
Silicon	32.4
Aluminum	9.8
Calcium	2.7
Magnesium	0.86
Sodium	3.9
Potassium	1.7
Iron	3.7
Titanium	0.31

Parts per Million

Arsenic	6.3
Barium	240
Boron	22
Cadmium	0.1
Chloride	45
Chromium	1.9
Cobalt	6
Copper	9
Fluoride	330
Lead	34
Manganese	960
Mercury	<0.1
Molybdenum	0.9
Nickel	22
Phosphorus	930
Selenium	<0.1
Sulfur	73
Vanadium	14

6.0 AIR QUALITY AND METEOROLOGY

6.1 Introduction and Scope

The monitoring program for air quality and meteorology was carried out in accordance with the provisions of the Development Monitoring Plan, as modified by conditions of approval issued by the Oil Shale Supervisor. During 1980, two ambient air stations monitored gaseous constituents, particulates, and various meteorological variables. A 60-meter meteorological tower is located at Air Quality Station 023. The tower has wind speed and direction instruments at three levels, and also has instruments for temperature and delta temperature. Meteorological data were also gathered at two mechanical weather stations. All the above systems are operated on a continuous basis. Visual range measurements were made using a method combining photography and microdensitometry. Measurements were made on a six-day interval from late April to early June and during October and November. Section 6.2 discusses the results from the air quality monitoring program and Section 6.3 discusses the supporting meteorological measurements.

6.2 Ambient Air Quality

6.2.1 Gaseous Constituents

6.2.1.1 Scope

Continuous monitoring of gaseous constituents in the ambient air on and near the C-b Tract included:

- Sulfur Dioxide (SO_2)
- Hydrogen Sulfide (H_2S)
- Ozone (O_3)
- Carbon Monoxide (CO)
- Oxides of Nitrogen (NO_x)
- Nitrogen Dioxide (NO_2)
- Nitric Oxide (NO)

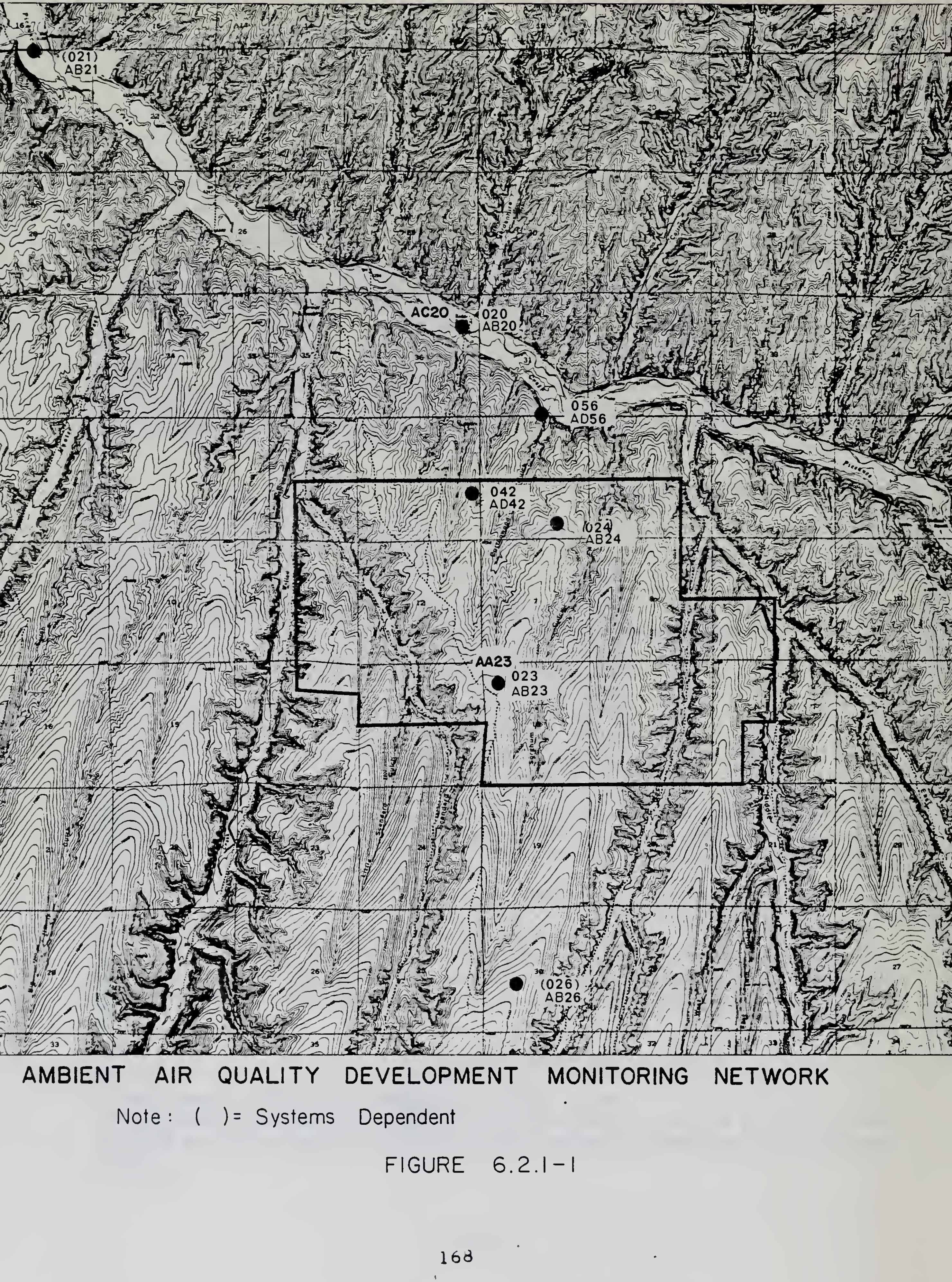
Monitoring of these constituents is required under the Lease stipulations. Data collected during 1980 have been reduced and analyzed to determine trends in or relationships among any of the variables.

6.2.1.2 Objectives

The objectives of the analyses reported here are: to demonstrate compliance with applicable ambient air quality standards, to detect any long-term or seasonal trends in monitored variables, and to attempt to identify sources of pollutants if levels of those pollutants are significantly above baseline levels.

6.2.1.3 Experimental Design

The air quality development monitoring network is shown in Figure 6.2.1-1; systems-dependent stations are currently inactive. Station AB23 is equipped to monitor the constituents listed in Section 6.2.1.1,



AMBIENT AIR QUALITY DEVELOPMENT MONITORING NETWORK

Note: ( )= Systems Dependent

FIGURE 6.2.1-1

and has provided a continuous air quality record since the beginning of the baseline monitoring period. Station AB20 was equipped during 1979 to measure all constituents except the sulfur gases (SO_4 and H_2S). The monitoring at both sites is accomplished with continuous analyzers. The constituents monitored at each site, the frequency of data collection, and the start-up dates are shown in Tables 6.2.1-1 and 6.2.1-2.

The analyzers in both stations are, where applicable, the E.P.A. reference or equivalent methods for their respective constituents. Quality assurance procedures have been provided in the Development Monitoring Data Reports. Specifications for all instruments are listed in Table A6.2.1-1. Positive data values below the instrument detection limit were not entered as zeroes into the data base; the actual values were entered. Negative values appearing on magnetic tape were entered as zeroes.

6.2.1.4 Methods of Analysis

The methods used in the analysis of air quality data are as follows:

6.2.1.4.1 Concentrations as Time Histories

Concentration time histories are analyzed to detect variation in the data over time. Such patterns may be composed of three or more components. Almost all environmental variables will have a distinct random component of time-based variation. The complex interrelationships among these variables will assure some level of unpredictable behavior. A second frequently-seen component is periodic variation, such as a seasonal cycle. Gaseous constituents related to meteorological variables will show a detectable periodic component synchronized with seasonal variations in meteorology. Superimposed on these two patterns may be a trend component indicating an increase or decrease with time in the level of an air contaminant. Visual representations of the monitored data for the gaseous constituents at Stations AB20 and AB23 are presented in the form of time-series plots in Figures A6.2.1-1 through A6.2.1-6. Each figure also indicates the lower detection limit for the instrument. As stated previously, positive data values below the instrument detection limit were not entered into the data base as zeroes; the actual values were used. Negative values appearing on magnetic tape were entered as zeroes.

A linear regression model was applied to air quality data with respect to time to provide initial screening for linear trends. Results of this analysis are discussed in 6.2.1.5.1.

6.2.1.4.2 Comparison with Standards

Maximum concentrations from air quality monitoring were compared with ambient air quality standards.

6.2.1.4.3 Correlation with Wind Speed and Direction

Correlation of wind speed and direction with measured concentrations of gaseous constituents may tend to show patterns

TABLE 6.2.1-1

AMBIENT AIR-QUALITY & METEOROLOGY DATA DESCRIPTION

Symbols represent sampling frequency on Table 6.2.1-2

Measurement: Category and Location	Start-up Date	SO_2	H_2S	Particulates (3)	Ozone	NO_x	NO	NO_2 (1)	CO	Horizontal Wind Speed	Horizontal (2) Wind Direction	Vertical (2) Wind Speed	Relative Humidity	Air Temperature	Precipitation	Evaporation	Barometric Pressure	Solar Radiation	Temperature Difference	Mixing Height	Visible Range	Height
Air-Quality Trailer																						
AB20	a) Jan. '78			0						X	X				Z							
	b) July '78				X	X	X	X	Y					X								
	c) July '79	X																				
AB21	Systems Dependent																					
AB23	Nov. '74	X	X	0	X	X	X	X	Y						Z	S.	X	X				
AB24	a) Sys. Dep.			0						X	X			X								
	b) 1984	X	X																			
AB26	May '81	X		0	X	X	X	X	Y	X	X			X	Z							
Weather Sta & Hi-Vol Sampler																						
AD42	Feb. '78			0						Z	Z			Z								
AD56	Feb. '78			0						Z	Z			Z								
Met. Tower @																						
3m	Nov. '74												X*									
10m	Nov. '74									X	X	X		X					2			
30m	Nov. '74									X	X			X								
60m	Nov. '74									X	X	X		X					2			
Upper Air Studies																						
Acoustic Radar 020	Oct. '77																			U		U
Visibility, Sta.060	Apr. '78																				V	

* @ 1m

(1) $(NO_2) = (NO_x) - (NO)$
(2) Std. Deviation calculated.
(3) Also Size Distributions during Visibility Study

TABLE 6.2.1-2

Ambient Air Quality and Meteorology Sampling and Reporting Frequencies

Symbols appear on Table 6.2.1-1

Symbol	Sampling Frequency	Minimum Average Time	Minimum Report Frequency	Description
X	10-seconds	5-minutes	1-hour	AQ & Low Alt. Meteorology
Y	5-minutes	5-minutes	1-hour	AQ & Low Alt. Meteorology
Z	Continuous	1-hour	1-hour	Precipitation
0	Every 3rd day	24-hours	24-hours every 3rd day	Particulates
2	20-seconds	5-minutes	1-hour	Temp. difference from 10-meter to 60-meter on Met. Tower
U	14-seconds		1-hour	Inversion Height/Mixing Layer from Acoustic Radar
V	7 times per day every 6th day for 10 days in Spring and 10 days in Fall	Hourly	Daily (with hourly max/min)	Joint Visibility study with C-a from Hunter Creek Site
S	Weekly during growing season	Weekly	Weekly	Evaporation

leading to identification of contributing sources. Regional air contaminant levels generally will not display consistent variation with wind direction. The influence of a major air contaminant source will be most pronounced within a given sector of wind direction, the sector being smaller for sources closer to the monitoring site due to dispersion effects which accompany transport of air contaminants. The effect of wind speed is less direct. One way in which wind speed relates to measured concentrations is through influence on atmospheric stability and therefore on contaminant dispersion. This relationship can be difficult to predict. High winds may aid in dispersion and thereby reduce concentrations, but they may also transport polluted air parcels.

The gases monitored at the C-b Tract are not the products of nearby sources, but rather are the result of dispersion of many sources over a wide region with concentrations near instrument lower detection limits. For this reason, wind correlations are not presented for sulfur gases, nitrogen oxides, and carbon monoxide.

6.2.1.4.4 Comparison of Maximum and Mean Concentrations

A comparison of maximum and mean concentrations of air contaminants may provide some insight into the causal factors contributing to observed levels of those contaminants. There are three cases to consider: (1) the ratio of maximum to mean is close to one, and both maximum and mean values are low compared to ambient standards; (2) the ratio is close to one, but both maximum and mean are significant, compared to ambient standards; and (3) the ratio is high, and the mean is low compared to ambient standards.

In the first case, the closeness of maximum to mean indicates that the factors contributing to ambient concentrations are relatively consistent. Low levels observed indicate the absence of substantial contaminant sources near the monitoring site. Often, this situation is indicative of regional air contaminant levels in clean-air areas. Relatively minor local influences combined with highly dispersed contributions from distant sources result in stable, low levels of air contaminants.

The second case will most often occur where there is a geographical concentration of major sources of air contaminants, particularly where there is little variation in meteorology. This situation will frequently correlate with a high degree of urbanization or industrial development in the immediate vicinity of a monitoring site or in an area consistently upwind of the site. The case not mentioned, i.e., the ratio, maximum and mean all high, would fit the same pattern of analysis, except for a higher degree of meteorological influence or more variable contributions.

The third case, a low mean value coupled with a high ratio indicates the absence of nearby major stationary sources of air contaminants. Unlike the first case, however, the high ratio of maximum to mean is indicative of some major influence which is subject to time variation. One example would be the short-term effects of a portable source. Relatively infrequent natural phenomena such as carbon monoxide and particulates from forest fires, or downward entrainment of stratospheric ozone are other examples. The consistent feature is the absence of effects of nearby urbanization.

6.2.1.5 Discussion and Results

6.2.1.5.1 Results of Analysis of Concentrations as Time Histories

For the sulfur gases, hydrogen sulfide and sulfur dioxide, excursions above the detection limit are infrequent and of short duration. This is consistent with past results in sulfur gas monitoring.

The oxides of nitrogen more frequently reach measurable levels but daily mean values are usually below the detection limit. The background concentration of ozone (discussed below) is sufficient to cause generally measurable nitrogen oxides, particularly nitrogen dioxide.

Carbon monoxide is probably the only gaseous constituent directly emitted into the atmosphere from Tract operations in sufficient quantity to be routinely measurable. Even so, daily means are often at or below the detection limit. There does not appear to be any pattern in the occurrence of peak levels.

Ozone is the only gas monitored consistently having a measurable mean concentration. Also, it has closely approached the ambient air standard. This behavior is of interest because there are no development-related emissions of the type and magnitude to cause elevated ozone levels. The possible causes of ozone excursions are discussed in a later section.

Since ozone is the product of atmospheric reactions and also present in the stratosphere, rather than an emitted substance, its concentration is subject to variation due to stratospheric down-mixing or to changes in the intensity of insolation, providing the driving force for ozone-producing reactions. This results in a seasonal pattern in the ozone plots, with the highest mean concentrations in summer, and lowest in winter. Over the history of ozone monitoring on-Tract, this seasonal pattern coupled with the large random component has been consistently present.

In a format suggested by EPA's SAROAD data base, statistical distributions of ozone along with the annual arithmetic mean and five highest hourly averages, ozone values are presented for calendar year 1975 through 1978 on Table 6.2.1-3.

Table 6.2.1-4 shows the results of the application of the linear model to air quality data with respect to time. The four values are defined in the figure legend. In those cases where the linear model did not fit the data, items four and five are left blank.

Short-term linear trends are apparent at both 020 and 023 only for carbon monoxide. A slightly negative short-term trend in SO_2 concentration was shown at 023, with no apparent trend at 020. Oxides of nitrogen showed slightly positive trends at 020, but no apparent trends were exhibited at 023. No linear trends were shown in data for either ozone or hydrogen sulfide.

TABLE 6.2.1-3

OXIDENTS (O_3) AT STATION AB23

(1975 - 1980)

OXIDENTS (O_3)

FOR CALENDAR YEAR 1975

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7160

Annual Arithmetic Mean (ug/m³): 69.0

5-Highest Hourly Averages (ug/m³):

			HOUR ENDING
1.	151.3	6/26	1400
2.	147.9	6/26	1500
3.	142.4	2/23	2300
4.	136.9	5/22	0300
5.	136.9	5/22	0400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m³)	3
3.0 - 20.9	39
21.0 - 40.9	1160
41.0 - 60.9	1752
61.0 - 80.9	1385
81.0 - 100.9	2205
101.0 - 120.9	530
121.0 - 140.9	83
141.0 - 160.0	3
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1976

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8239

Annual Arithmetic Mean (ug/m³): 62.0

5-Highest Hourly Averages (ug/m³):

			HOUR ENDING
1.	124.0	4/26	1500
2.	123.0	4/26	1600
3.	122.4	4/26	1700
4.	120.3	4/26	1300
5.	119.3	4/26	1400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m³)	15
3.0 - 20.9	50
21.0 - 40.9	1197
41.0 - 60.9	2611
61.0 - 80.9	2890
81.0 - 100.9	1232
101.0 - 120.9	241
121.0 - 140.9	3
141.0 - 160.0	0
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1977

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7874

Annual Arithmetic Mean (ug/m³): 79.0

5-Highest Hourly Averages (ug/m³):

			HOUR ENDING
1.	164.0	8/24	1100
2.	163.8	8/24	1200
3.	162.6	8/24	1400
4.	162.5	8/24	1000
5.	158.1	7/31	0900

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m³)	2
3.0 - 20.9	4
21.0 - 40.9	105
41.0 - 60.9	1232
61.0 - 80.9	3405
81.0 - 100.9	2066
101.0 - 120.9	842
121.0 - 140.9	179
141.0 - 160.0	35
GREATER THAN 160.0	4

OXIDENTS (O_3)

FOR CALENDAR YEAR 1978

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8081

Annual Arithmetic Mean (ug/m³): 81.6

5-Highest Hourly Averages (ug/m³):

			HOUR ENDING
1.	160.9	8/27	1800
2.	157.0	8/27	1700
3.	153.0	8/27	1900
4.	153.0	9/8	1500
5.	149.1	9/8	1800

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m³)	0
3.0 - 20.9	2
21.0 - 40.9	184
41.0 - 60.9	1290
61 0 - 80.9	2897
81.0 - 100.9	2200
101.0 - 120.9	1145
121.0 - 140.9	328
141.0 - 160.0	34
GREATER THAN 160.0	1

OXIDENTS (O_3)

FOR CALENDAR YEAR 1980

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8448

Annual Arithmetic Mean (ug/m³): 76.3

5-Highest Hourly Averages (ug/m³):

1.	153.6	1/3
2.	130.5	1/3
3.	129.5	5/24
4.	129.5	6/5
5.	127.5	5/24

Number of Hourly Concentrations in Ranges:

RANGE:	NO. OF VALUES
0.0 - 2.9 (ug/m³)	5
3.0 - 20.9	6
21.0 - 40.9	157
41.0 - 60.9	1559
61.0 - 80.9	3685
81.0 - 100.9	2505
101.0 - 120.9	503
121.0 - 140.9	27
141.0 - 160.0	1
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1979

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8693

Annual Arithmetic Mean (ug/m³): 76.0

5-Highest Hourly Avarages (ug/m³):

1.	245.8	1/20
2.	203.5	1/20
3.	195.2	1/20
4.	192.5	1/20
5.	154.6	1/20

Number of Hourly Concentrations in Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m³)	0
3.0 - 20.9	0
21.0 - 40.9	115
41.0 - 60.9	1335
61.0 - 80.9	3622
81.0 - 100.9	3167
101.0 - 120.9	443
121.0 - 140.9	6
141.0 - 160.0	0
GREATER THAN 160.0	5

TABLE 6.2.1-4

Summary of Air Quality Trend Analysis ($\mu g/m^3$)
Trailer 020 and 023

Indicator Variable		Short Term 020	Short Term 023	Long Term 020	Long Term 023
SO_2	1.	0.2944/12	0.4300/12	0.2650/39	0.3083/70
	2.	0.6108	0.0349	0.4229	0.5884
	3.		-0.0027		
	4.		0.3730		
NO_x	1.	0.5369/12	0.6726/12	4.1871/52	1.1733/69
	2.	0.0006	0.8292	0.0045	0.0033
	3.	0.0039		-0.0042	-0.0011
	4.	0.7043		0.1506	0.1220
NO	1.	0.1342/12	0.3026/12	2.7330/52	0.7499/70
	2.	0.0037	0.3539	0.0241	0.0052
	3.	0.0012		-0.0028	-0.0008
	4.	0.5871		0.0976	0.1092
NO_2	1.	0.4069/12	0.4877/12	1.4530/52	0.6601/69
	2.	0.0016	0.1856	0.0002	0.5584
	3.	0.0027		-0.0014	
	4.	0.6478		0.2433	
O_3	1.	25.5337/12	38.5128/12	27.8179/52	37.2919/71
	2.	0.2845	0.2919	0.0052	0.0174
	3.			-0.0045	0.0037
	4.			0.1462	0.0793
CO	1.	65.5982/12	88.0740/12	405.4950/45	454.5643/64
	2.	0.0086	0.0012	0.0001	0.0001
	3.	-0.4304	-0.7572	-0.4471	-0.4852
	4.	0.5150	0.6690	0.5457	0.4179
H_2S	1.		0.4476/12	0.0613/23	0.4836/69
	2.		0.1773	0.7670	0.0005
	3.				-0.0005
	4.				0.1654
TSP.	1.	10.15/12	10.82/12	12.01/52	12.11/75
	2.	0.1044	0.2457	0.3894	0.2595
	3.				
	4.				

NOTE: Entries in the table mean the following:

1. Mean/Number of paired observations
2. α - to be compared with selected α. (α= 0.05)
3. Slope - slope is units per month
4. r^2 value

Long-term linear trends in sulfur dioxide were not apparent in the data. Trends in oxides of nitrogen were all slightly negative. Long-term trends in ozone data were slightly negative at 020 and slightly positive at 023. Carbon monoxide exhibited negative long-term trends at both stations. Long-term trends in hydrogen sulfide data at 023 were very slightly negative, and no trend was apparent at 020.

In summary, monitoring of ambient gases during the period of this report produced little new information. Sulfur gases, nitrogen oxides and carbon monoxide continue to be present at low levels.

Carbon monoxide displayed significant negative long- and short-term trends. The linear trends that were shown in other air pollutant concentrations were very slightly positive or negative. Most linear trends are negligible. Ozone, while measured at significant levels, may be characterized as having a seasonal, background type of pattern, with large random variations compared to seasonal mean levels.

6.2.1.5.2 Results of Comparison of Maximum Concentrations with Ambient Standards

Table 6.2.1-5 lists the maximum measured concentrations of gaseous constituents for averaging times corresponding to standards. For all but one of the gaseous criteria pollutants the maximum concentrations are well below the standards; the one exception is ozone. This pattern has existed since the beginning of ambient monitoring at the C-b Tract in the fall of 1974. This is consistent with the overall character of the region with very low population density and most development activities subject to stringent regulation of potential air quality impacts.

In the case of ozone, a combination of elevated background levels and observed excursions exists indicating downmixing from the stratosphere.

During the period of this report, one new high value was established. On January 20, 1979 a one-hour average ozone concentration of 246 ug/m^3 was recorded at Station AB23. Although this ozone value is in excess of the ambient air standard of 240 ug/m^3, it does not in itself constitute a violation of that standard, which defines a violation as more than one expected exceedance per year, based on three years of monitoring. Other than the 246 ug/m^3 value, no other one-hour average has reached the level of the standard. Causes for high ozone concentrations were discussed in Volume III of the Final Baseline Report.

In summary, the results of monitoring the gaseous constituents through October, demonstrate continued compliance with ambient air standards at the C-b Tract.

6.2.1.5.3 Results of Correlation of Air Quality Data with Wind Speed and Direction

Figure 6.2.1-2 depicts the wind dependence

TABLE 6.2.1-5

Comparisons of Maximum Background Levels with Ambient Standards

Applicable Standard	Constituent	Averaging Time	Standard Limit ($\mu g/m^3$)	Maximum Reading ($\mu g/m^3$)	Data Precision ($\mu g/m^3$)	Station With Max. Reading	Date of Maximum Reading
Colorado Ambient Air Quality Standards	Particulates	Annual	75	14.5	0.6	023	1978
	Particulates	24-Hour	260	178(1) 162(2)	11 10	024	11/27/74(1) 11/29/74(2)
	H_2S	1-Hour	142	72.2	8	023	12/22/74
National Ambient Air Quality Standards							
Primary	SO_2	Annual 24-Hour	80 365	1.3 43.1	15 15	021 & 024 021	1974 - 1975 6/16/75
Secondary	SO_2	3-Hour	1300	87.7	15	023	12/21/74
Primary	NO_2	Annual	100	5.0	6	020	1975 - 1976
Primary	Particulates	Annual 24-Hour	75*** 260	11.0 178	0.6 11	023 024	1978 11/27/74
Secondary	Particulates	Annual 24-Hour	60*** 150	11.0 178(1) 162(2)	0.6 11 10	023 024	1978 11/27/74(1) 11/29/74(2)
Primary	CO	8-Hour 11-Hour	10,000 40,000	4501.9 4650.9	100 100	020 020	6/03/75 6/04/75
Primary	Oxidant	1-Hour	240(3)	246.0(4)	20	023	1/20/79

*** Geometric mean

(1) Highest maximum reading

(2) Second highest maximum reading

(3) Standard is exceeded if $\geq$ 3 expected exceedances occur above this value over a three year interval

(4) Represents the only exceedance to date

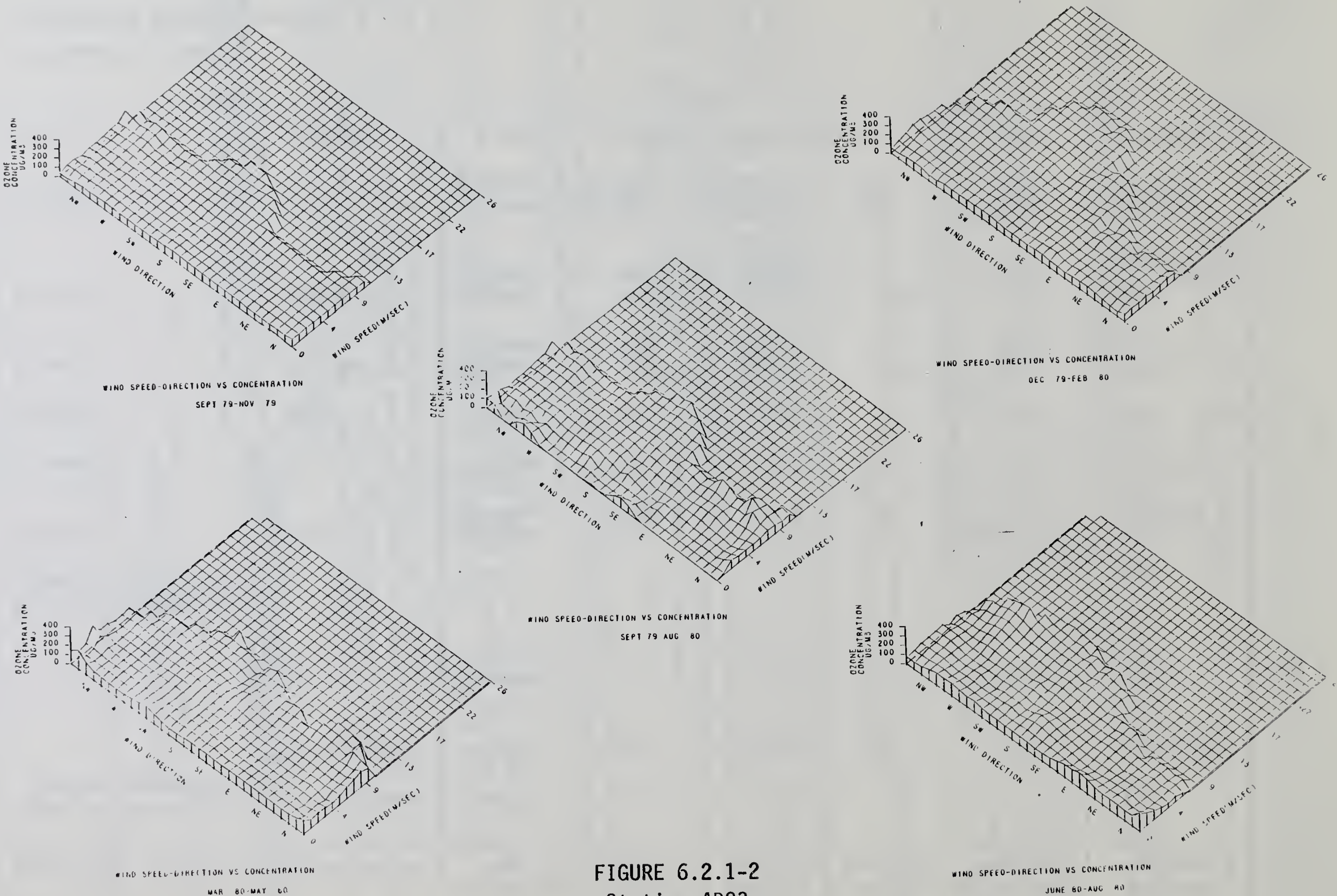


FIGURE 6.2.1-2
Station AB23
WIND SPEED-DIRECTION VS. OZONE CONCENTRATION
1979 - 1980

of ozone at Station AB23 by means of three dimensional plots for quarterly periods. Each of the plots takes the form of a plateau, indicating the lack of wind direction dependence that would otherwise result if specific sources were present. Concentrations of ozone with respect to wind direction are provided as concentration roses in Appendix Figures A6.2.1-7 and A6.2.1-8.

6.2.1.5.4 Results of Comparison of Maximum and Mean Concentrations

Table 6.2.1-6 lists the maximum and mean values and the ratio of maximum to mean for each gaseous constituent. Both maxima and means for nitrogen dioxide, sulfur dioxide, hydrogen sulfide, and carbon monoxide are small compared to their respective standards. For these constituents, the low values are more significant than the ratios in indicating the overall absence of significant sources of these air contaminants. However, in all four cases the maximum-to-mean ratio is considerably larger than it is for ozone. This shows that only in the case of ozone is the background concentration within an order of magnitude of the maximum value, indicating a greater consistency of monitored values.

6.2.1.6 <u>Conclusions</u>

(1) Compliance with State and Federal ambient air standards continues at the C-b site. Adoption of the 240 ug/m^3 standard for ozone provided additional increment above background levels which accommodated most excursions, excluding the single exceedance noted earlier.

All other parameters continue to be monitored at levels far below appropriate standards.

(2) Negative linear trends were shown for carbon monoxide for both long-term and short-term data. The linear correlations shown for other gaseous constituents were accompanied by slopes of near zero for the regression data.

(3) Sources of air contaminants on and near the C-b site include many small sources of combustion product gases and fugitive dust. No single source is of sufficient size to be detected on the basis of wind vs. concentration correlations.

6.2.2 Particulates

6.2.2.1 <u>Scope</u>

Monitoring of ambient particulates is required by the Oil Shale Lease Stipulations and by Federal and State Air Quality Regulations. Measurements were made at Stations AB20, AB23, and AD56. During visibility measurement days, size-distributed samples were taken at Station AB23.

6.2.2.2 <u>Objectives</u>

The objectives of the monitoring of ambient particulates are: (1) to demonstrate compliance with applicable regulations; (2) to

TABLE 6.2.1-6

Maximum, Mean* and Max/Mean Ratio** for Air Quality Constituents ($\mu g/m^3$)

Constituent	Symbol	Station AB20			Station AB23		
		Max	Mean	Max/Mean	Max	Mean	Max/Mean
Nitrogen Dioxide	NO_2	26	0.7	27	41	0.8	51
Sulfur Dioxide	SO_2	21	2.0	11	21	1.1	19
Hydrogen Sulfide	H_2S	-	-	-	111	1.0	111
Carbon Monoxide	CO	1700	77.8	22	3800	91.7	41
Ozone	O_3	122	50.1	2	154	75.4	2
Total Suspended Particulates	TSP	49	8.4	6	41	9.1	4

* Arithmetic Means

** Based on 1-Hour Averages

determine whether long-term trends exist; and (3) to attempt to identify particulate sources.

6.2.2.3 Experimental Design

The EPA reference method for particulate monitoring, the high volume sampler, is employed at all stations to measure particulates. The samples are located such that the air intakes are approximately 4.6 meters above ground level. An Anderson particle sizing head is used in place of the standard filter assembly when taking size-distributed samples. As yet, there is no EPA reference method for particle-size sampling.

6.2.2.4 Method of Analysis

Methods used in analyzing particulate data were multiple regression analyses using a set of meteorological parameters and qualitative examination of time series plots.

6.2.2.5 Discussion and Results

The time-series plot of particulate concentrations for Station AB23 (Figure 6.2.2-1) is used for this discussion. One dominant feature of the plot is the seasonal variability. Maximum concentration levels typically occur in the late spring with minimum levels in the winter. Concentrations during the late summer months are variable, but are generally lower than the spring peaks.

Histograms depicting the frequency distributions of particulate concentrations (Figures 6.2-2-2 and 6.2.2-3) show the predominance of concentrations less than 20 to 25 ug/m^3. The composite histogram also displays a skewed log-normal distribution, typical of particulate concentrations that are influenced by random variation in meteorological parameters.

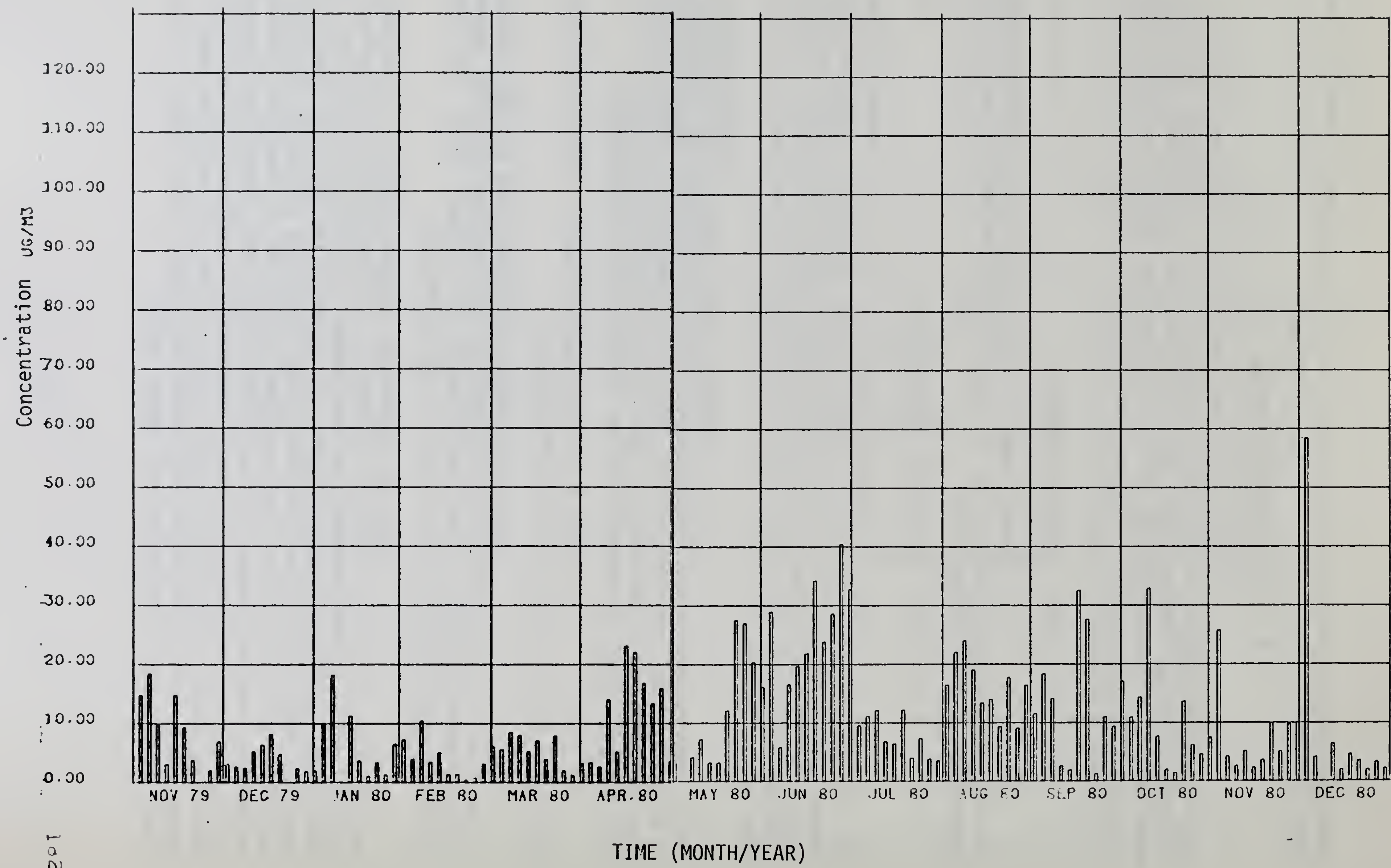
Table 6.2.1-4, shown previously, lists the maximum annual and 24-hour particulate concentrations.

The Federal Primary Standards have not been exceeded at any time. On a 24-hour basis, the maximum value remains 178 ug/m^3 compared to the standard of 260. A wider margin exists on an annual basis. The Federal Secondary Annual Standard of 60 ug/m^3 is not approached.

Plots of particulate concentrations vs. wind speed and direction for Station AB23 are presented in Figure 6.2.2-4. In general, the data show a marked dependency on wind speed, as would be expected in a situation where particulate concentrations are primarily the result of fugitive dust sources. This factor is most evident during the spring and summer quarters. During the rest of a typical year, substantial periods of snow cover reduce the background level and change this relationship with wind. Particulates generated then on or near the Tract will show a much smaller dependence on wind speed, sometimes actually resulting in higher concentrations at lower wind speed. These source specific contributions become less significant compared to background levels during the spring and summer period.

FIGURE 6.2.2-1

Time Series of 24-Hour Particulate Concentrations at Station AB23



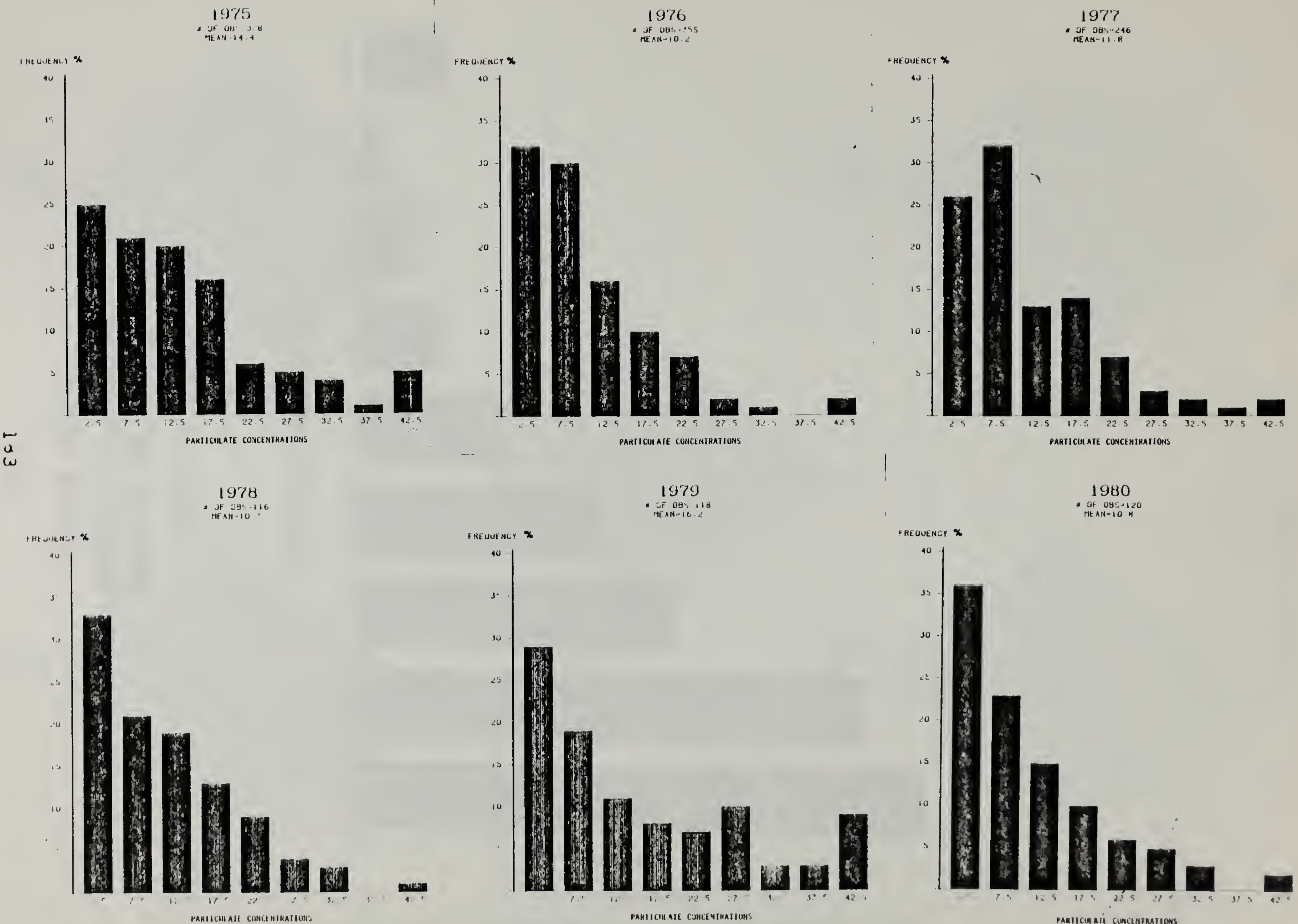


Figure 6.2.2-2 Frequency Distribution of Particulate Measurements by Year Station (AB23)

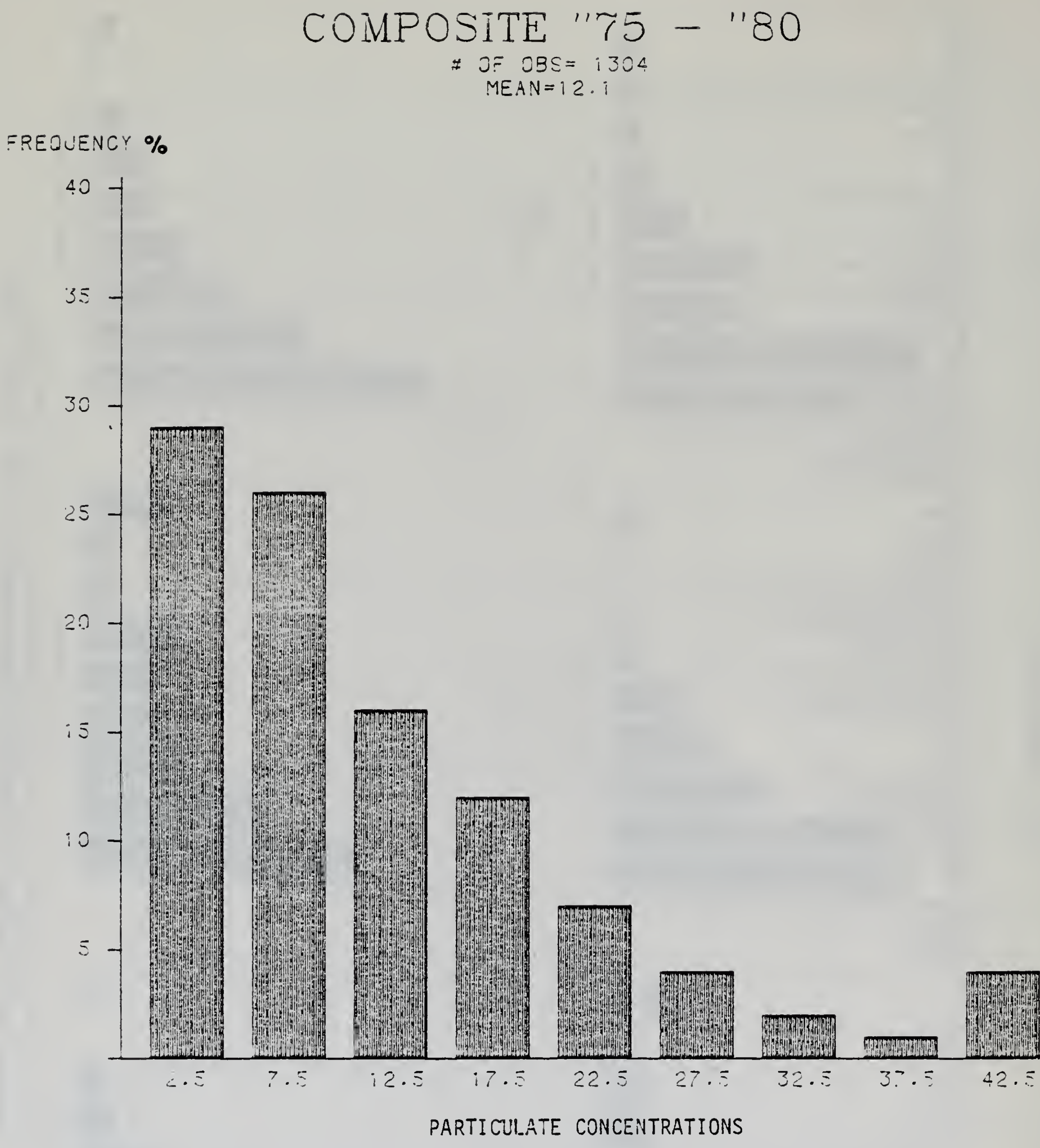


FIGURE 6.2.2-3

COMPOSITE PARTICULATE
FREQUENCY DISTRIBUTION
STATION (AB23)

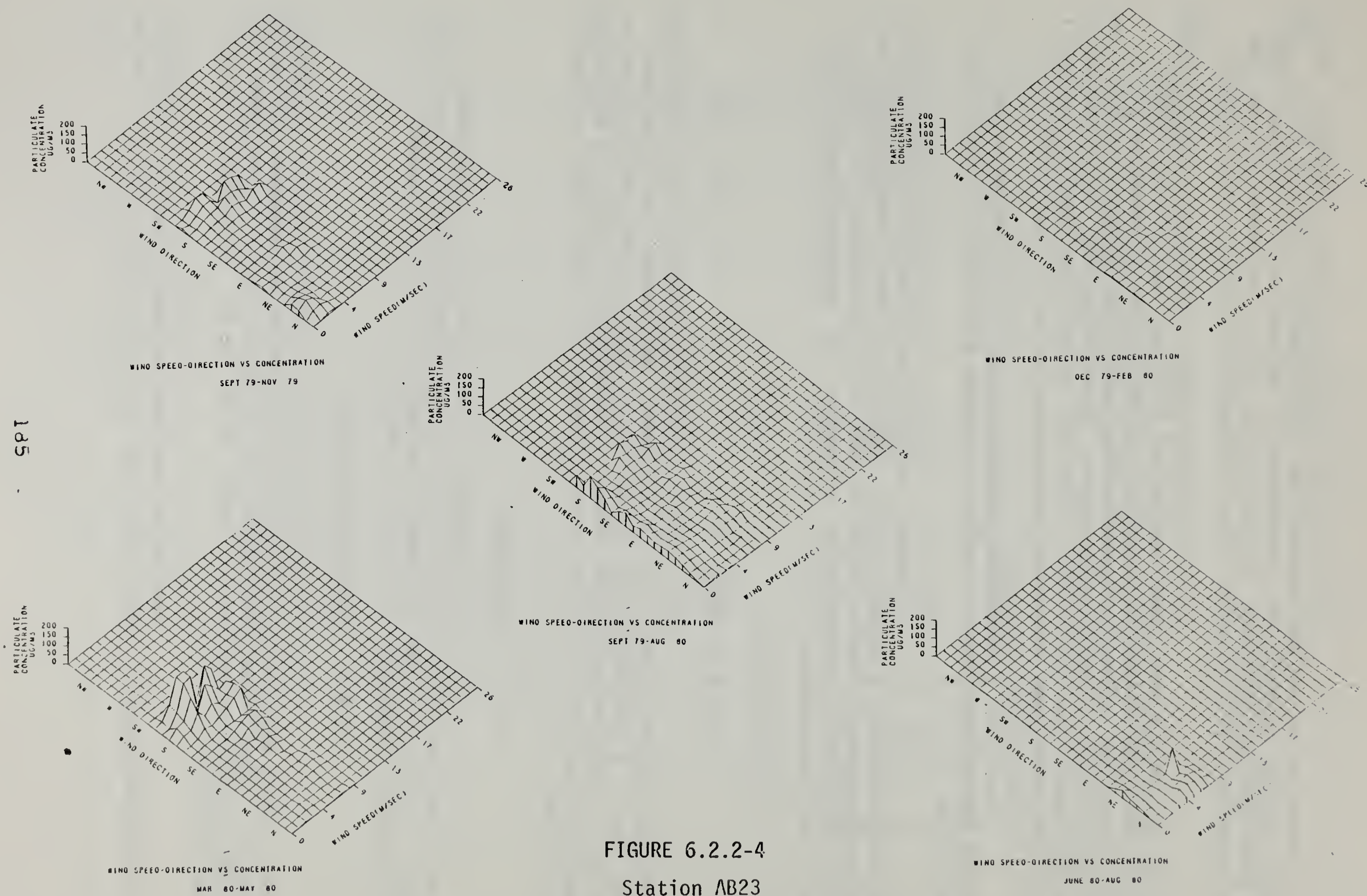


FIGURE 6.2.2-4

Station AB23

WIND SPEED-DIRECTION VS. PARTICULATE CONCENTRATION

1979 - 1980

There is no definite wind direction dependence indicated as shown by particulate concentration roses (Appendix Figure A6.2.2-1). The virtual absence of particulate measurements in the wind sector centered around the north-northeast direction is indicative of the low incidence of winds from that direction. Wind direction values correspond to 24-hour average values.

The relationships between particulate loading and precipitation, average wind speed, and maximum wind speed were tested. Table 6.2.2-1 shows the results of the analysis. Particulates are negatively but weakly correlated with precipitation; strong correlation is prevented due to the infrequent nature of precipitation events. Correlations with average and maximum wind speeds were significantly better with maximum wind speed only slightly better when correlated with 24-hour average particulate concentrations.

Size distributions of particulate concentrations obtained during the visibility monitoring program are shown in Figures 6.2.2-5 and 6.2.2-6.

In summary, particulates in the C-b vicinity are primarily fugitive dust with rural origin, particularly those responsible for maximum concentrations. Seasonal trends in particulate concentrations suggest a general dependence on meteorological parameters. No long-term trends are evident in particulate data.

6.2.3 Visibility

6.2.3.1 Scope

The visibility monitoring program has been cosponsored by the C.B. and Rio Blanco Shale Oil Projects. Measurements were taken every sixth day for a total of ten days in the Spring quarter, 1980, and ten days in the Fall. There are no State or Federal requirements for visibility monitoring; however, the program is required under the Federal Oil Shale Lease Environmental Stipulations.

6.2.3.2 Objectives

The objectives in taking visibility measurements are to establish baseline visibility levels for the Piceance Basin, to identify any trends in visibility, and to attempt to establish correlations between visibility and meteorological or air quality parameters.

6.2.3.3 Experimental Design

Visibility data were obtained by means of telephotography from an observation site approximately eight miles southwest of Piceance Creek on a ridge between Hunter Creek and Dry Gulch. This site was chosen for its proximity to the C-a and C-b Tracts, as well as for its accessibility and range of views.

Photographs are taken at hourly intervals throughout the measurement days in each of four views as shown on Figure 6.2.3-1. The use

TABLE 6.2.2-1

Correlation of Particulate Data With Precipitation, Average Wind Speed, and Maximum Wind Speed

	Precipitation	Average Wind Speed	Maximum Wind Speed
Correlation Coefficient	-0.162	0.309	0.313
Significance	NS[1]	0.0007	0.0005
No. of Observations	114	118	119

[1]Not significant

PARTICULATE SIZE DISTRIBUTION SPRING 1980

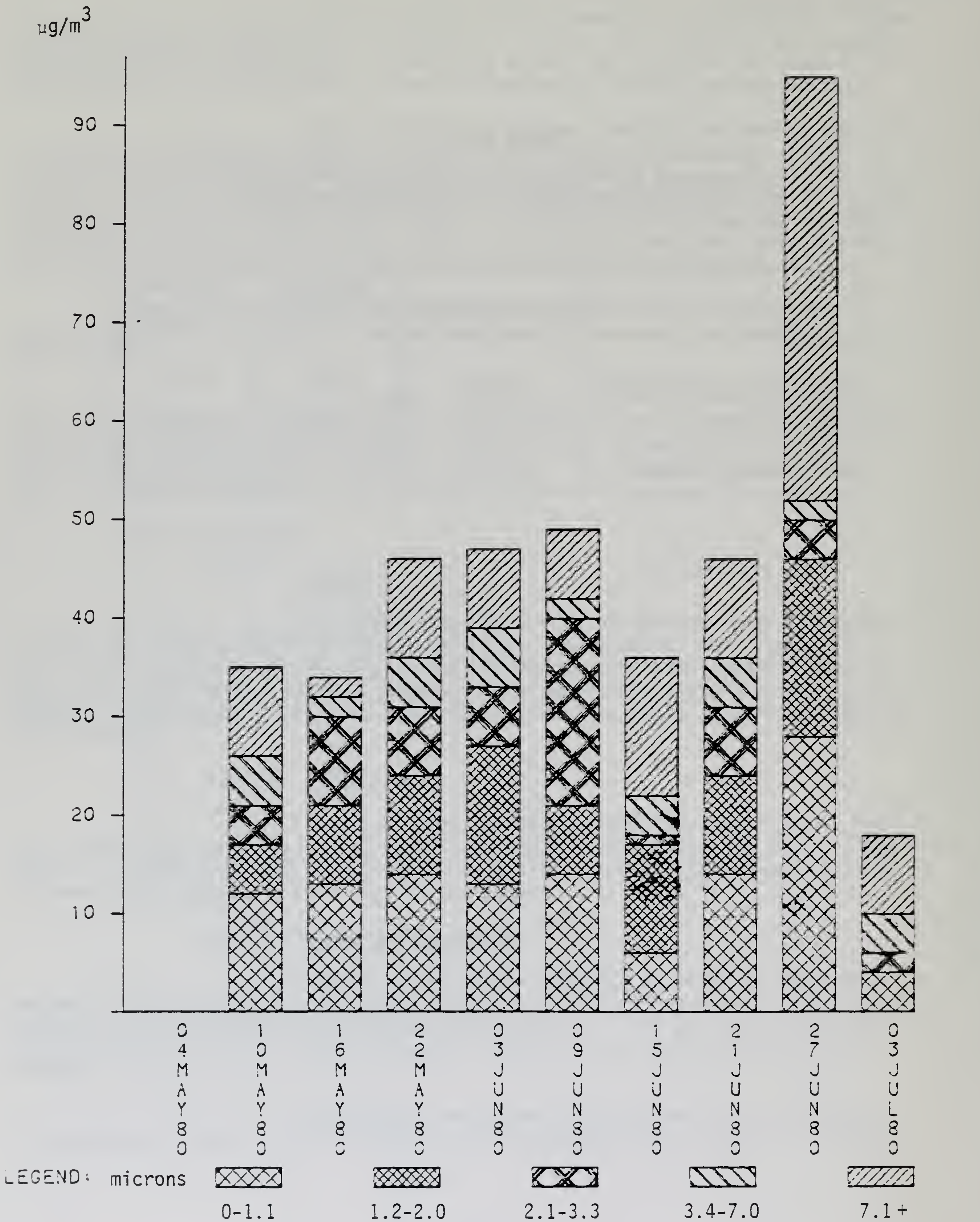


FIGURE 6.2.2-5

PARTICULATE SIZE DISTRIBUTION FOR FALL 1980

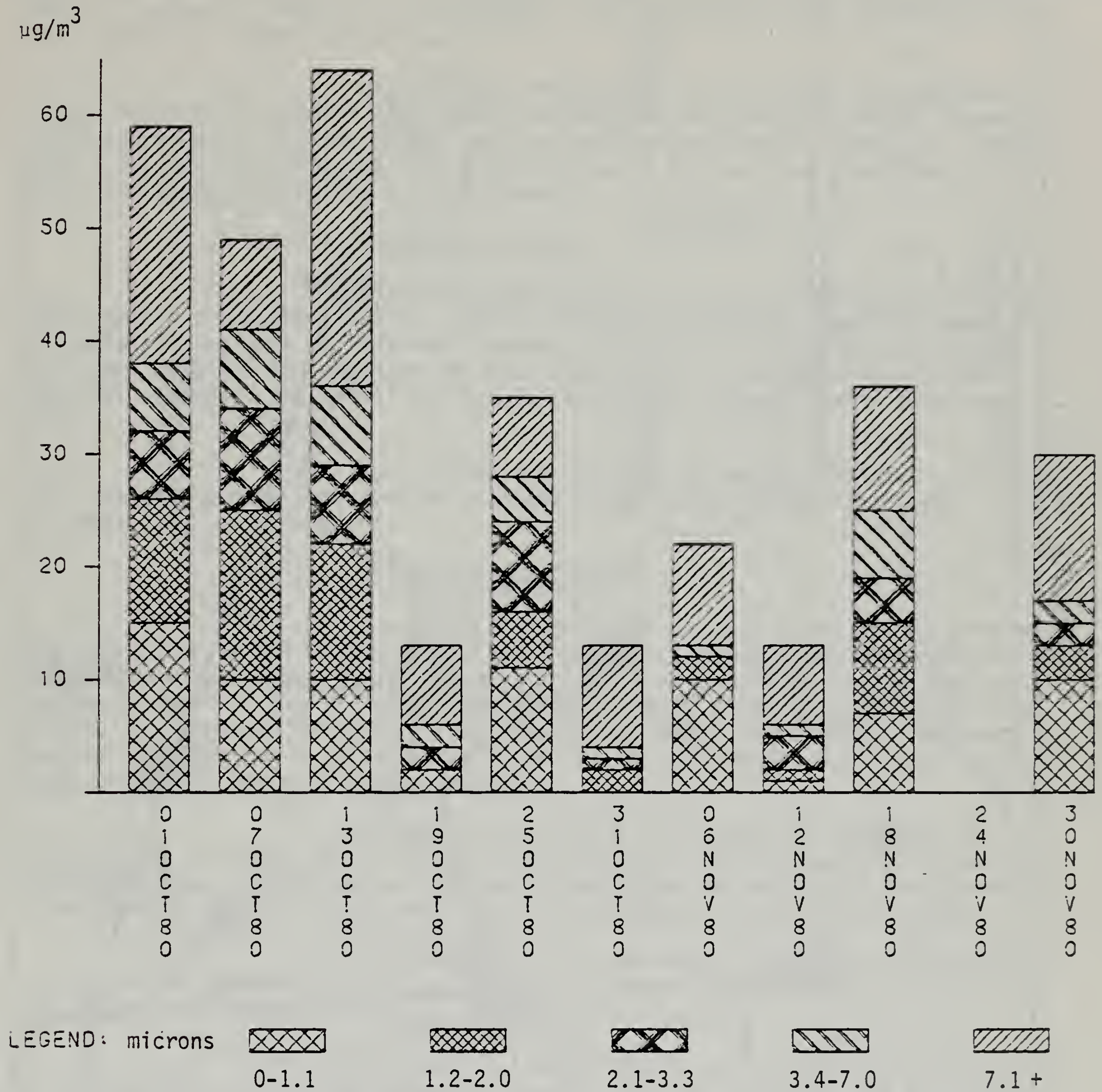
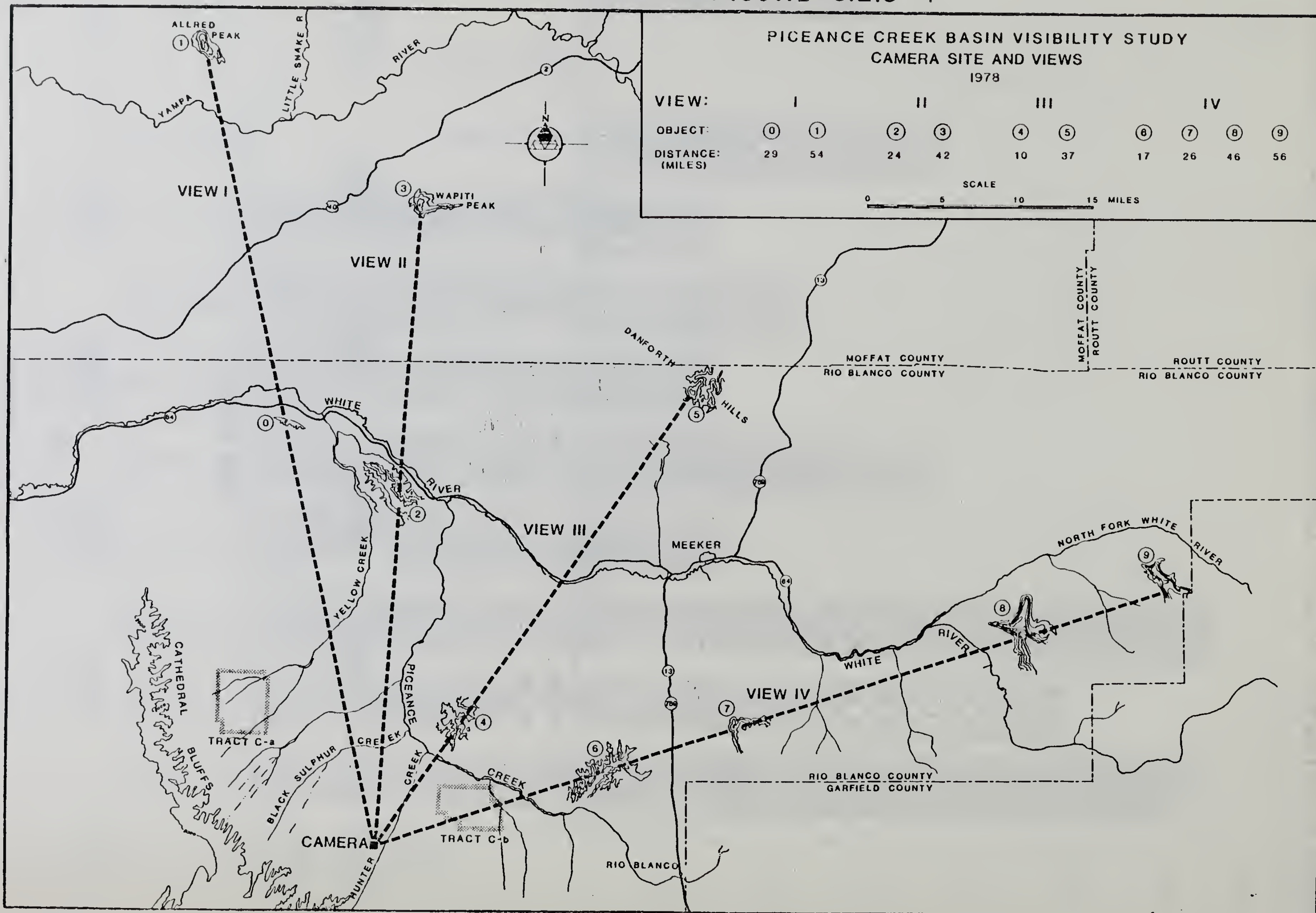


FIGURE 6.2.2-6

FIGURE 6.2.3-1


PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
1978
VIEW: I II III IV
OBJECT: 0 1 2 3 4 5 6 7 8 9
DISTANCE: (MILES) 29 54 24 42 10 37 17 26 46 56
SCALE
0 5 10 15 MILES
ALLRED PEAK
WAPITI PEAK
DANFORTH HILLS
YAMPA
RIVER
LITTLE SNAKE R
VIEW I
VIEW II
VIEW III
VIEW IV
MOFFAT COUNTY
RIO BLANCO COUNTY
ROUTT COUNTY
GARFIELD COUNTY
WHITE
RIVER
MEEKER
NORTH FORK WHITE RIVER
YELLOW CREEK
PICEANCE CREEK
BLACK SULPHUR CREEK
CATHEDRAL BLUFFS
TRACT C-a
TRACT C-b
CAMERA
HUNTER
RIO BLANCO

of at least two objects in each view enabled the measurement of visual range under a variety of visibility conditions. The locations of the observation site and objects are shown on the Figure.

Visual range information is extracted from the photographs by means of optical density measurements on the portions of the photograph representing a given object and the horizon sky directly above it. These densities, together with the actual object-camera distance and the object albedo, are used to calculate a visual range.

6.2.3.4 Method of Analysis

There have been only two years of seasonal visibility measurements since the baseline visibility study of 1975-76; therefore there is no basis for analysis of long-term trends in visibility. Visual range results have been compiled and averaged for each view and on a composite basis over monthly, seasonal, and annual periods to facilitate comparison with baseline data.

Correlation and multiple regression analyses using 1980 visibility data were used to evaluate visual range relationships with a set of meteorological parameters.

6.2.3.5 Discussion and Results

The results of the 1980 visibility monitoring program are summarized in the histogram of Figure 6.2.3-2. Visual range measurements, averaged over all views shown in Figure 6.2.3-1, were variable in May 1980 and somewhat higher in June. October measurements showed wide variation from 90 km to 170 km. November measurements were generally higher than those of October, and were less variable. Wide ranges in visibility during May and October were associated with synoptic weather patterns.

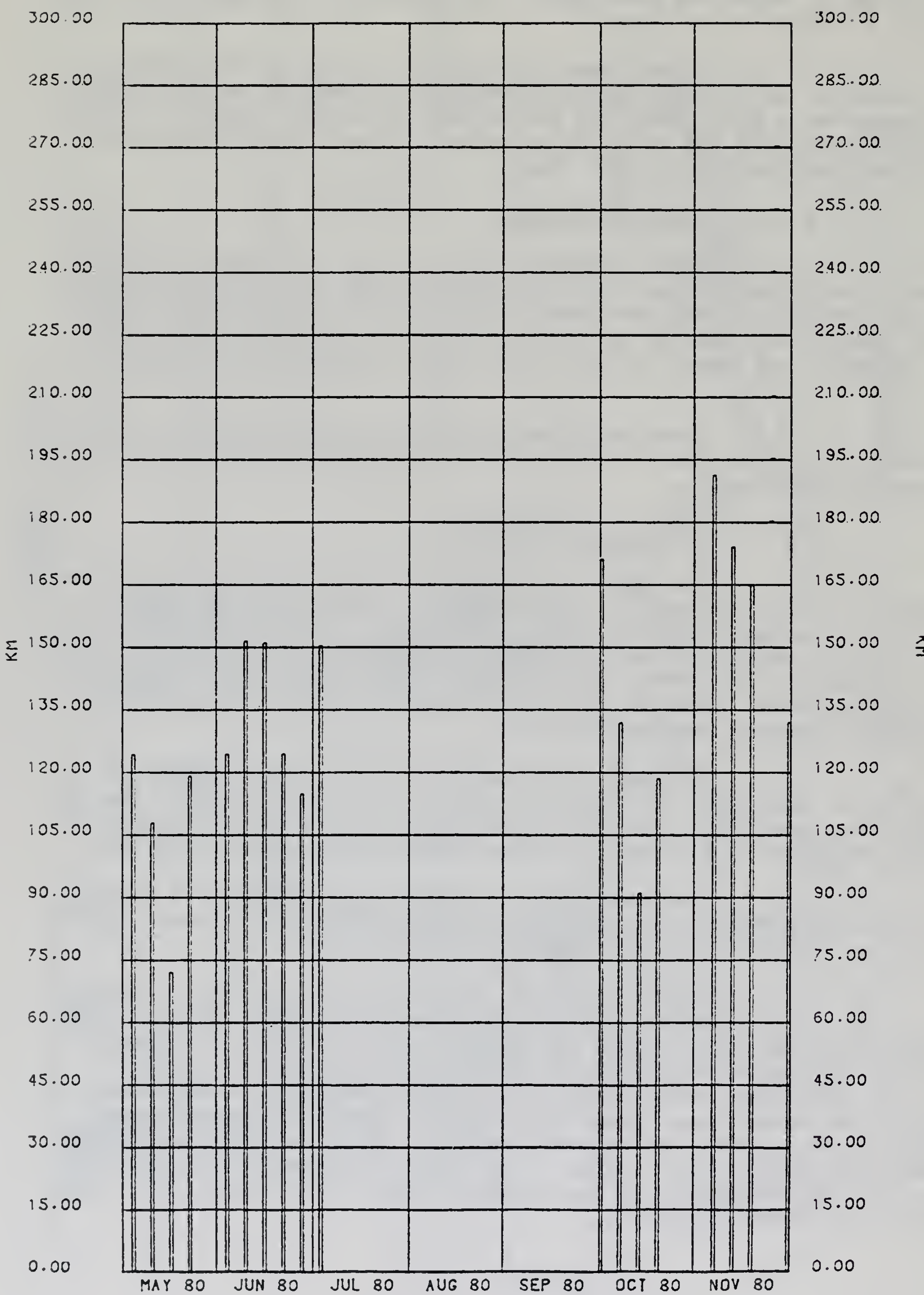
Figures 6.2.3-3 and 6.2.3-4 show the variation in visual range for each view. The inherent radiance of each target within the four different views produce variable visual range values on any single measurement time. The effects of view azimuth and solar geometry are taken into account.

The comparisons of 1980 visual range data to measurements of previous years are shown in Figure 6.2.3-5. Measurements taken in 1980 are within the range of variation shown for other years.

Table 6.2.3-1 is a summary of the regression analysis of visual range with respect to particulates, relative humidity, and wind speed. Data from Spring 1980 show negative relationship with wind speed for views I, II, and III, and a negative correlation with relative humidity for view IV. Although the correlation coefficients are not large, the inverse relationship is expected in that visual range should be reduced as higher wind speeds entrain more fugitive particulates, and weather events are often associated with higher wind speeds and reduced visual ranges. The inverse relationship with relative humidity may also be explained by the enhanced moisture and reduced visual range associated with weather conditions.

FIGURE 6.2.3-2

C-B TRACT SITE AREA DAILY AVERAGE VISUAL RANGE



VARIATION IN DAILY MEAN VISUAL RANGE BY VIEW

SPRING 1980

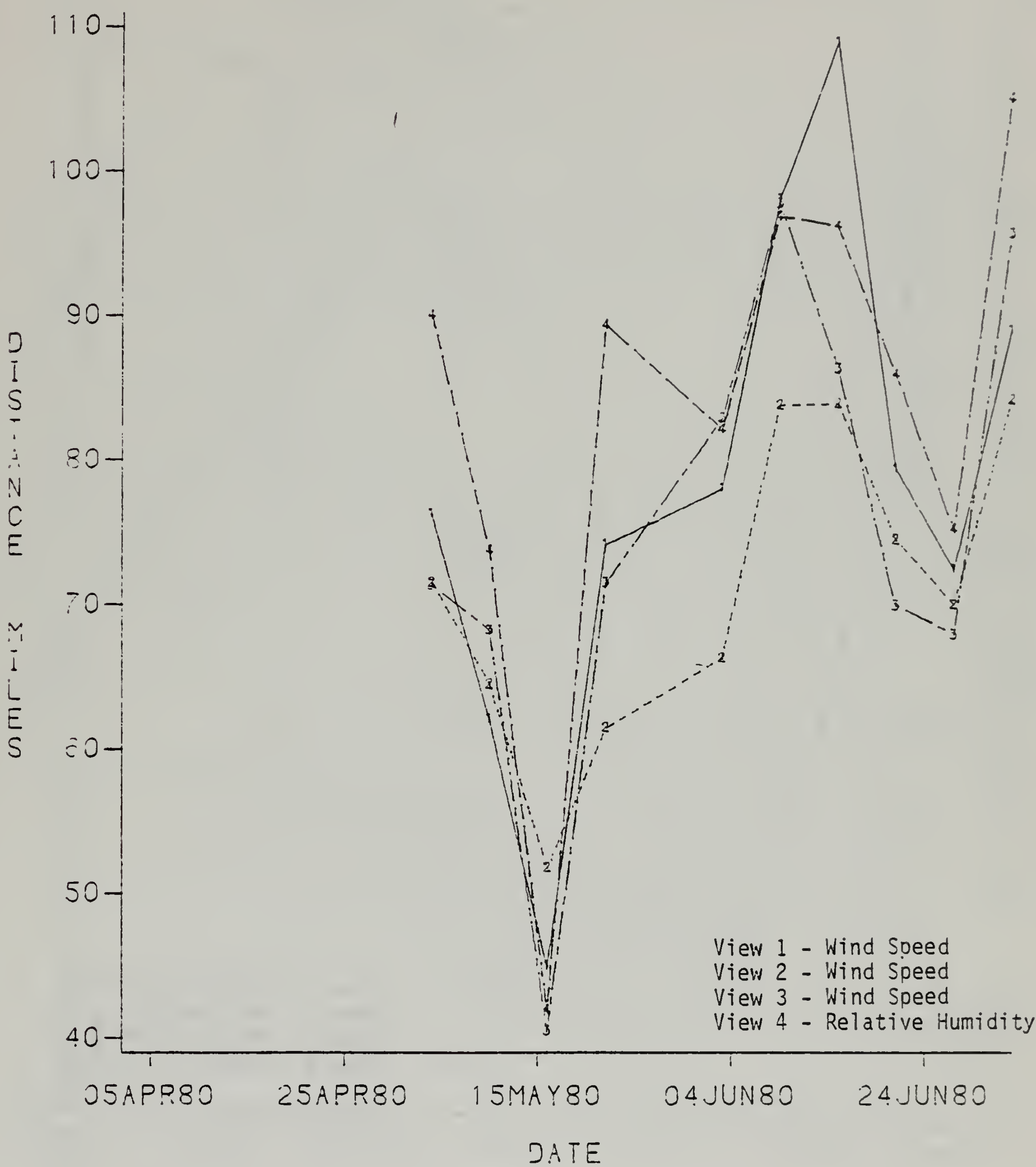


FIGURE 6.2.3-3

VARIATION IN DAILY MEAN VISUAL RANGE BY VIEW

FALL 1980

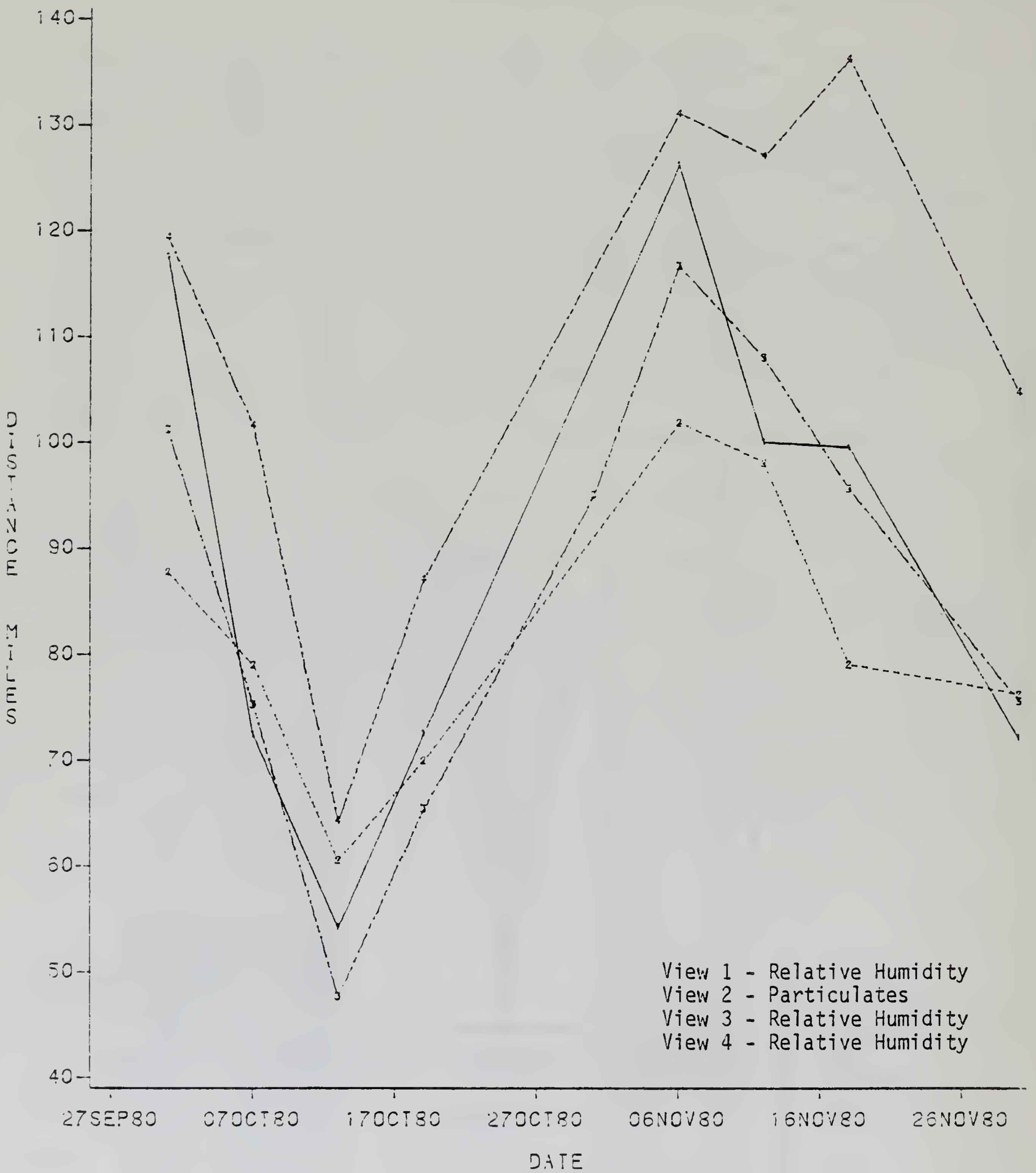


FIGURE 6.2.3-4

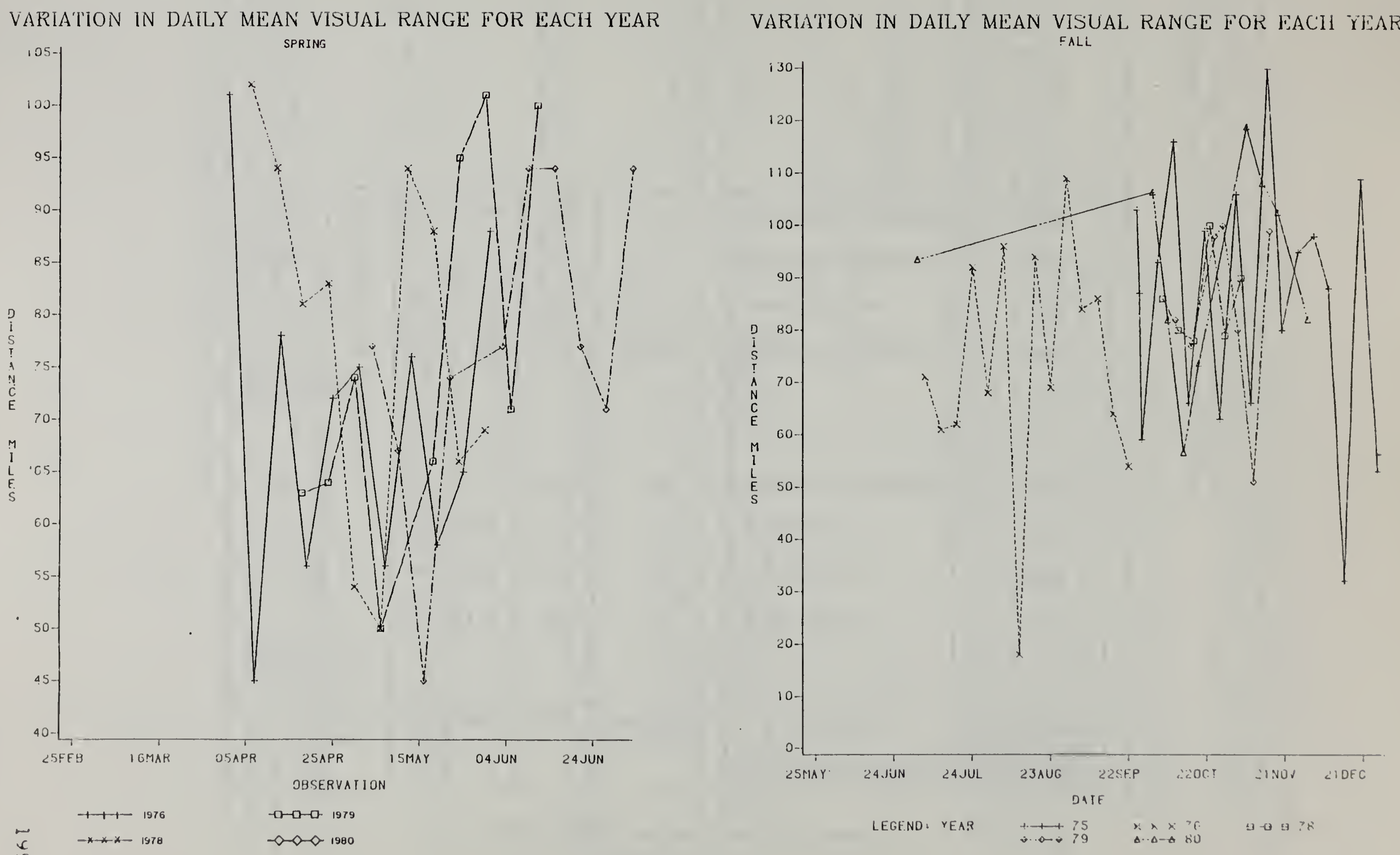

VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH YEAR
SPRING
DISTANCE MILES
OBSERVATION
25FEB 16MAR 05APR 25APR 15MAY 04JUN 24JUN
1976
1978
1979
1980
VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH YEAR
FALL
DISTANCE MILES
DATE
25MAY 24JUN 24JUL 23AUG 22SEP 22OCT 21NOV 21DEC
LEGEND: YEAR
75
79
80

FIGURE 6.2.3-5

TABLE 6.2.3-1

Visual Range (Miles) for 1980 Data

View	No. Obs.	Min	Max	Mean	Standard Deviation	Most Highly Correlated Variable	
						Variable	Correlation Coefficient
<u>SPRING 1980</u>							
I	21	45	116	81	18	Wind speed	-0.32
II	24	46	106	72	14	Wind speed	-0.30
III	23	41	110	78	19	Wind speed	-0.17
IV	24	47	118	80	19	Relative humidity	-0.38
<u>FALL 1980</u>							
I	22	53	126	86	20	Relative humidity	-0.06
II	21	61	102	80	11	Particulates	+0.08
III	24	31	117	79	23	Relative humidity	-0.33
IV	24	32	136	94	26	Relative humidity	-0.36

Data from the Fall measurement program show a similar inverse relationship between visual range and relative humidity for views I, II, III, and IV. The direct relationship between particulates and visual range for view II cannot be physically explained, but the low correlation coefficient (0.08) shows that the correlation is negligible.

Multiple stepwise regression analysis of the 1980 visual range data showed that no reliable model for prediction could be found.

Average visual range for Spring 1980 was 78 miles. For the years 1976-1979, average Spring visual range was 72 miles. Visual range during Spring of 1980 appeared to be better than the mean for previous years. During Fall 1980, mean visual range was 85 miles. For previous years 1976-1979, the mean visual range for Fall measurements was 82 miles, showing that the Fall visual range appeared better than the previous years. No time trends in visual range are apparent based on presently available data.

6.3 Meteorology

6.3.1 Climatological Records

6.3.1.1 Scope

The climatological parameters include temperature, solar radiation, precipitation, evaporation, relative humidity, and barometric pressure. These records primarily serve as a historical data base to assess climatological effects principally on the biotic portion of the ecosystem so they may subsequently be sorted from potential man-induced effects.

6.3.1.2 Objectives

Objectives are to establish this historical data base to determine any cyclical or long-term trends that might exist as well as averages and extremes, as appropriate.

6.3.1.3 Experimental Design

The climatological network is shown on Figures 6.3.1-1a and 6.3.1-1b. Parameters measured, instrumentation used, sampling stations and minimum reporting frequency are presented in Table 6.3.1-1.

6.3.1.4 Method of Analysis

Table 6.3.1-2 presents a summary of data formats and analysis along with station identification. Data presentation and analysis techniques include histograms, plots, and tables for all variables. Time-series plots for all Class I indicator variables are in the time-series Supplements to the Development Monitoring (data) Reports and also in Figures A6.3.1-1 through A6.3.1-3 for November 1979 through October 1980.

TABLE 6.3.1-1

CLIMATOLOGICAL PARAMETER EXPERIMENTAL DESIGN

Parameter	Instrument	Station(s)	Computer Code	Minimum Reporting Frequency
Air Temperature	Aspirated Temperature Sensor	020	AB20	Hourly
		023	AB23	Hourly
		042	AD42	Hourly
		056	AD56	Hourly
Direct Solar Radiation	Pyranometer	023	AB23	Hourly in Daylight
Precipitation	Weighing Bucket	020	AB20	Hourly
		023	AB23	Hourly
		USGS015	WU15	Approximately Monthly Totals
		USGS022	WU22	Approximately Monthly Totals
		USGS050	WU50	Approximately Monthly Totals
		USGS058	WU58	Approximately Monthly Totals
		USGS070	WU70	Approximately Monthly Totals
		Little Hills	WR01	Daily
		Meeker 2	WR02	Daily
		Scandard Gulch on Roan Plateau	WR03	Hourly
		Corral Gulch	WR04	Hourly
		JQS Gage	WR05	Hourly
		East Fork Parachute Creek	WR06	Hourly
		East Middle Fork Parachute Creek	WR07	Hourly
	Tipping Bucket	MC1 to 9, 13	BC01 to 09, 13	Bi-Weekly
Evaporation	Pan	023	AB23	Daily During Growing Season
Relative Humidity	R. H. Sensor	023	AB23	Hourly
Barometric Pressure	Barometer	023	AB23	Hourly

TABLE 6.3.1-2

CLIMATOLOGICAL DATA SUMMARY

Variable	Item	Station	Type Presentation/Analysis	Figure - Table Number
Air Temperature	Daily Mean, Minimum, Maximum	AB20, 23 AD42, 56	Time Series Plots	*Section 4.2.3 *Section 4.2.3
	Monthly Values of Hourly Maximum, Mean, Minimum	AB20, 23	Tabular	Table A6.3.1.2
	Growing Season	AB23	Plot Table - Start, End, Length	Figure 6.3.1-3 Table A6.3.1-3
	Degree Days	AB23	Tabular	Table A6.3.1-3
Direct Solar Radiation	Daily Total	AB23	Time Series Plot	*Section 4.2.3
	Daily Mean, Maximum and Minimum for Month	AB23	Tabular - Values Corrected for missing data	Table A6.3.1-4
Relative Humidity	Daily Mean, Minimum, Maximum	AB23	Time Series Plot	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean and Minimum	AB23	Tabular	Table A6.3.1-5
Precipitation	Daily Total	AB20, 23	Time Series Plot	*Section 4.2.3
	Monthly Total	AB20, 23 WU15, 22 WU50, 58 WU70 BC01-09, BC13 WR01-07		Table A6.3.1-6a thru 6e
	Monthly Total	AB23	Histogram (with Growing Season)	Figure 6.3.1-3
	Annual Total 3 Month Running Total	AB20, 23 WU70 BC02-05	Tabular	Table 6.3.1-3
	Between Station Comparison	AB20, 23	Histogram	Figure 6.3.1-4
		AB20, 23 WU70 WR01 BC02-05 BC07-09	Regression Analysis	Table 6.3.1-4
	Regional	National Weather	Isohyets	Figure 6.3.1-5
Evaporation	Daily Mean	AB23	Time Series Plot (Pan)	*Section 4.2.3
	Daily Mean	AB23	Tabular - Pan and Lake	Table A6.3.1-7
Barometric Pressure	Daily Mean, Minimum, Maximum	AB23	Time Series Plot	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean & Minimum	AB23	Tabular	Table A6.3.1-8

*Supplements to the Development Monitoring (data) Reports

6.3.1.5 Discussion and Results

6.3.1.5.1. Temperature

Annual mean temperatures at the Tract (Station AB23) have averaged between 6 and 9°C over the past five years.

Between-station comparisons (Stations AB20 vs. AB23) indicate minimum temperatures 12°C cooler in Piceance Valley than on Tract due principally to cold air drainage associated with katabatic winds, with valley temperatures reaching extremes of -43°C since baseline. Minimum, average and maximum temperatures for periods 1975 through 1980 are shown in Table A6.3.1-2.

Growing season length and degree-day data are presented on Table A6.3.1-3. Growing seasons over the past five years have varied from 96 days in 1976 to 151 days in 1980, and the degree-days referenced to 18°C (Munn 1970) were highest in 1977 (193 degree-days) corresponding to a growing season of 96 days.

6.3.1.5.2 Solar Radiation

Direct solar radiation, as measured by a pyranometer, varied from a monthly average of 658 langleys per day in June near summer solstice to approximately 117 langleys in December near winter solstice; the 1980 data were similar to those of previous years. This variation approximates the yearly cycle in the daily peaks in the cosine of the sun's zenith angle. Values presented in Table A6.3.1-4 have been corrected for missing data by applying a correction factor. This correction factor is the ratio of average daylight hours per month to pyranometer channel "uptime" hours per month for cases where uptime exceeds 50% of the daylight hours per month. Values obtained for the Tract in June have been compared with values obtained for 40°N latitude (approximate Tract latitude) from Sellers, Physical Climatology as follows:

	Tract	Sellers
Clear Day Peak	725	700 ly/day
Monthly Average	658	592

Sellers "Average" terms included:

Q, direct beam solar radiation incident on earth surface	
+q, diffuse solar radiation incident on earth surface	389 ly/day
C_a, backscattering by clouds	164
A_a, backscattering by air molecules, dust, water vapor	39
TOTAL....	592 ly/day

Additional terms in Sellers peak (cloudless, dry day)

C_a, (no) absorption by clouds	25
A_a, (no) absorption by air molecules, dust, water vapor	83
TOTAL	700 ly/day

6.3.1.5.3 Relative Humidity

Annual means of relative humidty at the Tract, (Station AB23) have averaged between 54 percent and 56 percent over the past five years, with winter hourly minimums of ten percent and summer minimums of nine percent (Table A6.3.1-5).

6.3.1.5.4 Precipitation

Precipitation data, as indicated on Figures 6.3.1-1a and -1b and Table 6.3.1-1 include measurements near two air quality stations, four U.S.G.S. stream gauging stations, one U.S.G.S. station on the Roan Plateau, ten microclimate stations, and seven additional stations as required by the Water Augmentation Plan. Monthly totals over all stations are presented in Tables A6.3.1-6a through -6e for 1975 through 1979. Monthly averages at the U.S.G.S. stations are approximate only, inasmuch as sampling of these stations is randomized. Annual total and 3-month running totals and the 1-hour peaks for the past five years are given on Table 6.3.1-3. Regression analysis was performed among selected precipitation monitoring stations in order to determine potential correlations. The results are summarized on Table 6.3.1-4. The most significant correlation was between Stations AB20 and AB23 (r = 95%) which utilize identical sampling techniques. Monthly histographs for each year are presented on Figure 6.3.1-3, along with growing season information. The wettest of the five years was 1975, 9 cm above its nearest competitor (AB23). Lightest annual precipitation at AB23 was 35.8 cm in 1976. Peak rainfall for a 1-hour duration reached 4.3 cm on September 3, 1977. Between-station comparisons for AB20 and AB23 are portrayed on Figure 6.3.1-4 as histograms, showing the local nature of precipitation between Tract (AB23) and valley (AB20). Between-station differences in monthly totals of as much as 5.4 cm were observed in September, 1977.

The regional precipitation patterns are influenced by the local terrain and difference in elevation between plateau and river valley with the elevated areas usually receiving more precipitation than the valleys as reflected in the isohyets (Figure 6.3.1-5). The highest yearly-average total-precipitation area in the region is usually located near the Marvine Ranch station (elevation 7,800 feet) which receives its major precipitation in the Winter and Spring in the form of snow.

6.3.1.5.5 Evaporation

Evaporation during the growing season has been measured by an evaporation pan at Station AB23 in 1978 and 1979. Monthly totals (Table A6.3.1-7) ranged from 6.49 to 20.37 cm as "pan" values in 1979 compared to 11.24 to 25.08 cm in 1978; assuming a 0.7 pan coefficient, lake values respectively range from 4.54 to 14.26 cm in 1979 compared to 7.87 to 17.56 cm in 1978. Monthly comparisons (May-September) show decreases in total evaporation for all months in 1979 from 1978.

6.3.1.5.6 Barometric Pressure

Annual mean barometric pressures at Tract

FIGURE 6.3.1-1a
CLIMATOLOGICAL NETWORK
NEAR TRACT

WU70
ON SCANDARD
GULCH AT
ROAN PLATEAU

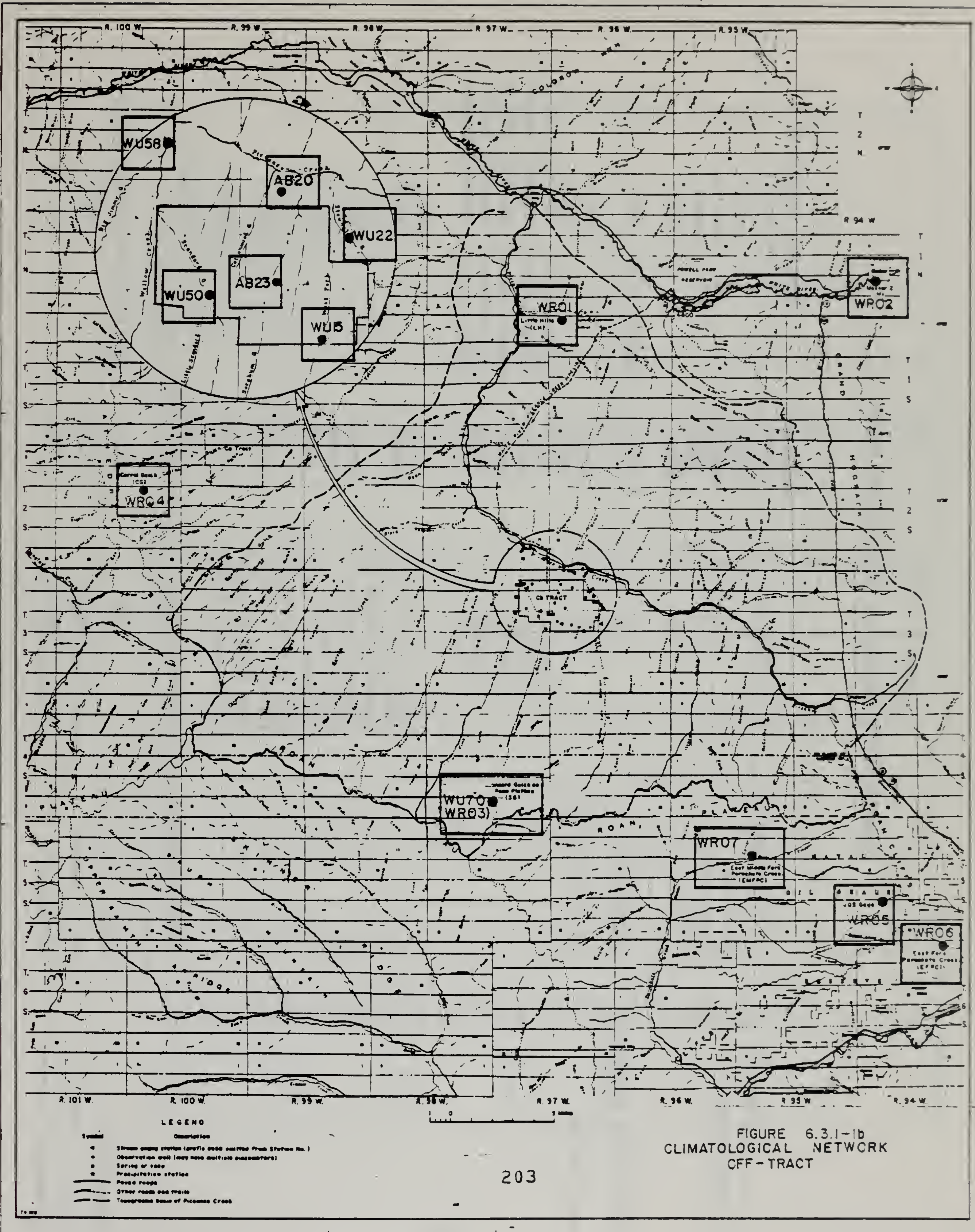


FIGURE 6.3.1-1b
CLIMATOLOGICAL NETWORK
OFF-TRACT

TABLE 6.3.1-1

CLIMATOLOGICAL PARAMETER EXPERIMENTAL DESIGN

Parameter	Instrument	Station(s)	Computer Code	Minimum Reporting Frequency
Air Temperature	Aspirated Temperature Sensor	020	AB20	Hourly
		023	AB23	Hourly
		042	AD42	Hourly
		056	AD56	Hourly
Direct Solar Radiation	Pyranometer	023	AB23	Hourly in Daylight
Precipitation	Weighing Bucket	020	AB20	Hourly
		023	AB23	Hourly
		USGS015	WU15	Approximately Monthly Totals
		USGS022	WU22	Approximately Monthly Totals
		USGS050	WU50	Approximately Monthly Totals
		USGS058	WU58	Approximately Monthly Totals
		USGS070	WU70	Approximately Monthly Totals
		Little Hills	WR01	Daily
		Meeker 2	WR02	Daily
		Scandard Gulch on Roan Plateau	WR03	Hourly
		Corral Gulch	WR04	Hourly
		JQS Gage	WR05	Hourly
		East Fork Parachute Creek	WR06	Hourly
		East Middle Fork Parachute Creek	WR07	Hourly
	Tipping Bucket	MC1 to 9, 13	BC01 to 09, 13	Bi-Weekly
Evaporation	Pan	023	AB23	Daily During Growing Season
Relative Humidity	R. H. Sensor	023	AB23	Hourly
Barometric Pressure	Barometer	023	AB23	Hourly

TABLE 6.3.1-3

PRECIPITATION (cm)

Station	Year	Annual Total: Calendar Year	Annual Total: Growing Season Year (April-March)	3-Month Total: March-April-May	3-Month Total: April-May-June	3-Month Total: May-June-July	1-Hour Maximum: Amount	1-Hour Maximum: Date
AB20	1975	54.5		18.6	15.9	12.0	0.29	8/10/75
	1976	42.4	53.8	14.3	10.3	12.7	0.43	6/14/76
	1977	42.4	30.7	9.8	5.9	6.7	4.32	9/3/77
	1978	40.3	47.9	14.7	9.2	8.7	0.76	6/5/78
	1979	41.4	36.7	15.3	12.0	11.3	0.89	11/20/79
	1980	35.2	45.4	13.7	8.0	9.5	0.23	12/24/80
AB23	1975	45.0		15.0	13.9	11.0	0.33	7/20/75
	1976	35.8	44.4	12.1	9.4	11.0	0.32	6/14/76
	1977	35.9	27.9	10.0	6.4	7.9	1.09	7/19/77
	1978	36.1	41.2	14.6	7.5	7.2	1.35	5/21/78
	1979	36.7	31.6	15.3	12.4	11.6	1.07	11/22/79
	1980	28.6	40.7	10.2	4.7	4.1	0.15	12/7/80 & 12/24/80
WU70	1975	49.1		15.8	14.7	12.1		
	1976	40.3	48.5	13.1	10.6	12.1		
	1977	40.3	35.4	14.4	7.3	5.2		
	1978	42.0	42.9	13.3	7.9	7.6		
	1979	40.6	38.6	13.3	11.1	10.6		
	1980*							
BC02	1975	23.6		9.4	7.5	5.6		
	1976	21.7	24.2	5.9	3.6	2.1		
	1977	25.0	15.9	6.3	3.9	4.4		
	1978	41.9	42.1	12.3	5.6	6.4		
	1979	19.3	25.3	6.2	4.5	4.4		
	1980	10.2	6.9	5.4	5.4	5.1		
BC03	1975	26.2		10.2	9.4	7.8		
	1976	23.1	29.6	7.8	5.0	3.3		
	1977	21.9	13.6	6.5	3.9	5.0		
	1978	42.2	40.1	14.1	5.6	5.7		
	1979	19.6	24.5	7.2	5.4	4.6		
	1980	10.9	7.1	5.8	5.8	4.7		
BC04	1975	26.3		11.6	8.9	5.7		
	1976	37.3	32.0	20.4	12.8	9.6		
	1977	32.8	19.5	0.2	0.2	17.9		
	1978	41.6	54.1	13.2	5.9	6.0		
	1979	19.9	26.3	5.2	2.9	2.2		
	1980	11.3	5.1	6.6	6.6	5.9		
BC05	1975	19.3		5.4	8.4	9.7		
	1976	10.6	20.2	1.0	2.9	3.2		
	1977	8.2	6.0	0.3	0.3	1.3		
	1978	34.1	28.0	11.0	4.9	3.9		
	1979	9.8	16.6	3.5	3.3	2.9		
	1980	7.2	4.4	4.1	4.1	3.3		

*1980 data not available

TABLE 6.3.1-4

MONTHLY PRECIPITATION REGRESSION

$y = a + bx$

Station (y)	Station (x)	a	b	r Coefficient of Correlation
WU70	AB20	1.17	0.61	0.58
WU70	AB23	1.43	0.62	0.57
WU70	WU15	2.15	0.50	0.57
AB23	AB20	-0.27	0.99	0.95
WR01	AB20	0.80	0.54	0.71
WR01	AB23	0.68	0.67	0.77
BC02	AB23	0.11	0.61	0.76
BC03	AB23	-0.24	0.73	0.81
BC04	AB23	-0.05	0.78	0.42
BC05	AB23	0.32	0.18	0.37
BC07*	AB23	0.63	0.47	0.42
BC08*	AB20	0.18	0.79	0.66
BC09*	AB20	-0.22	0.81	0.69

*In an attempt to show the degree of correlation that can be expected between microclimate spot-check precipitation data and continuously recorded precipitation data collected by weighing rain gage at stations AB20 and AB23, linear regressions were performed between AB23 and BC07 and between AB20 and BC08 and BC09. MC station BC07 is located approximately 1/4 mile East of, and can be expected to show a "good" correlation to, air quality station AB23; this degree of correlation is not evident. The January and February, 1978 precipitation data for MC station BC07 were considered suspect because of their extremely high values. When these two values were eliminated from the regression, AB23 vs BC07 showed a coefficient of correlation, r, of 0.70 with a = 0.15 and b = 0.55 - values much nearer those expected in the regression. Stations BC08 and BC09 are located approximately 1 mile downstream and upstream, respectively, of air quality station AB20 on Piceance Creek. They show better correlations than did AB23 and BC07 but still show better than 50% correlation with AB20.

FIGURE 6.3.1-3
MONTHLY TOTAL PRECIPITATION
AND TEMPERATURE VARIATIONS
STATION AB23

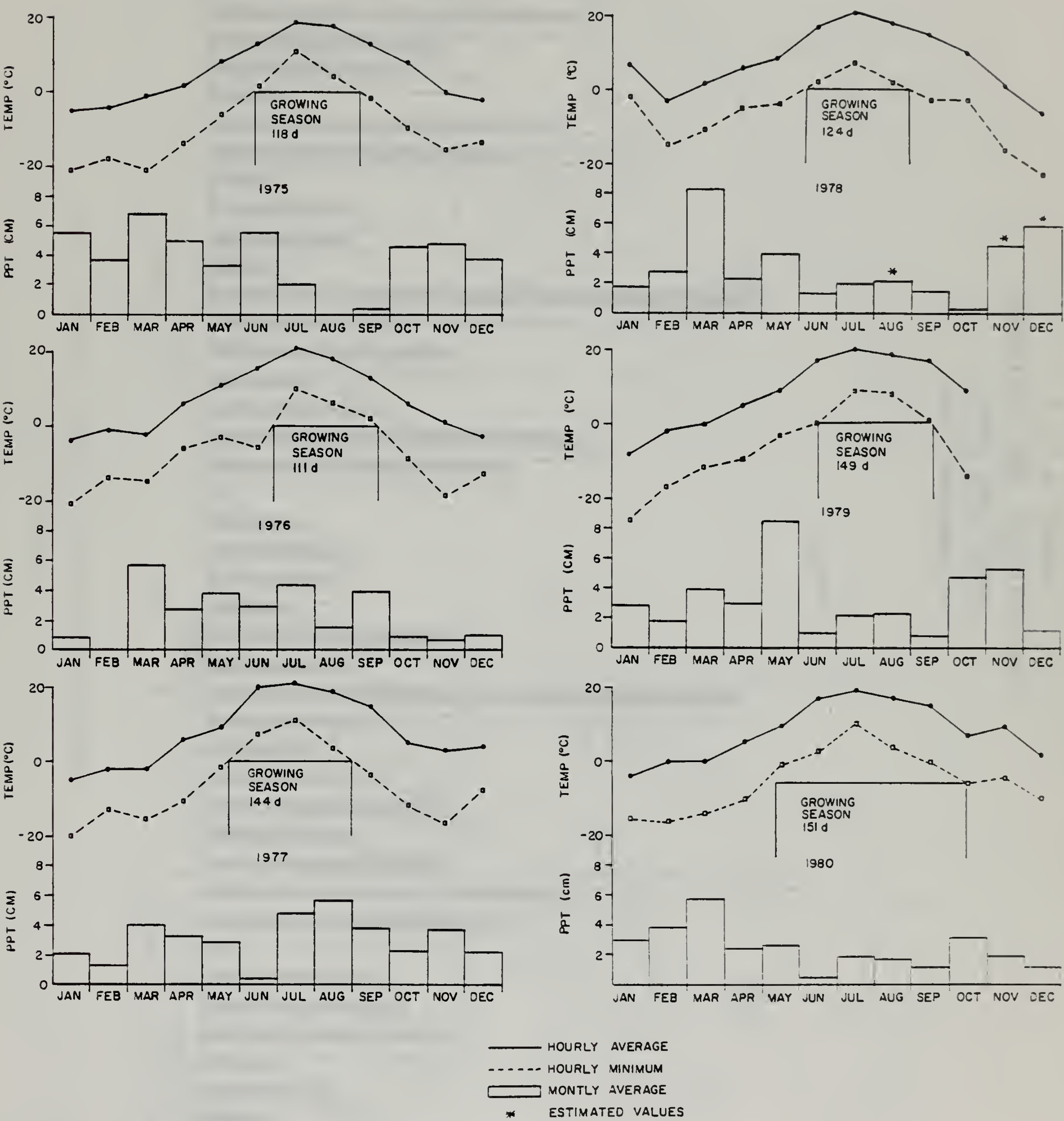


FIGURE 6.3.1-4
PRECIPITATION FOR STATIONS
AB20 AND AB23
x = Estimated Total

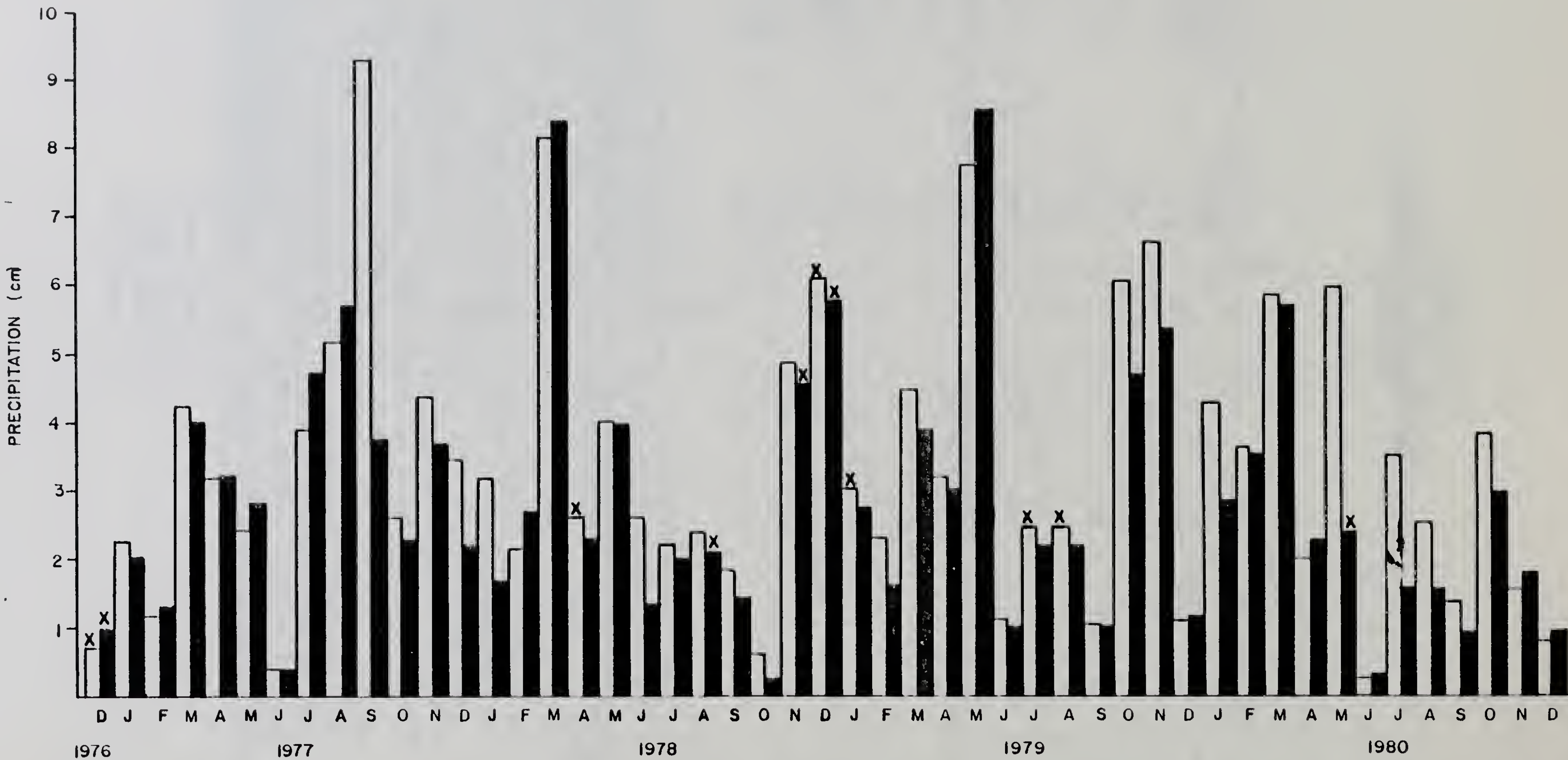


FIGURE 6.3.1-5

Regional Precipitation Patterns (Isohyets) (cm)

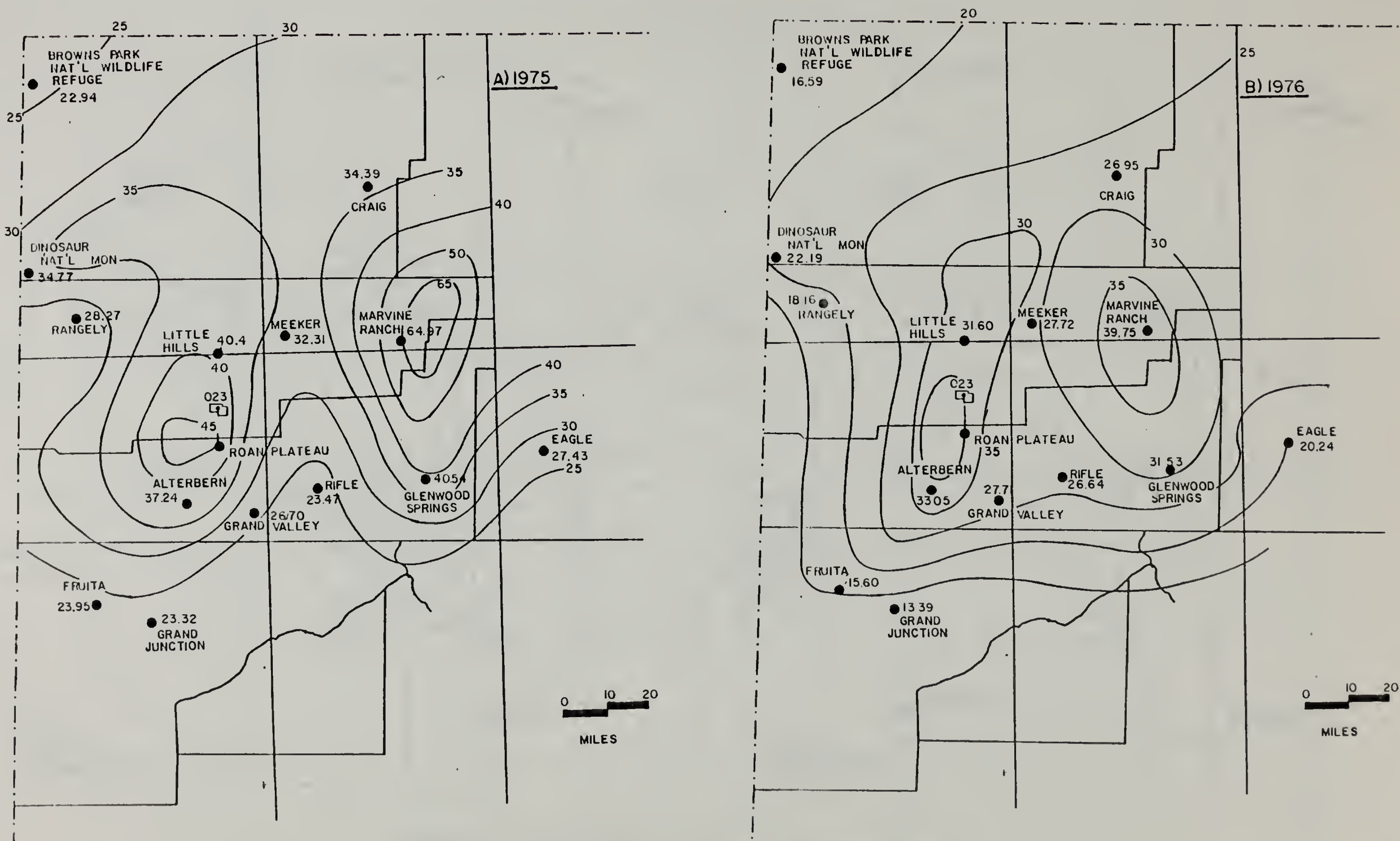


FIGURE 6.3.1-5 (Cont.)

Regional Precipitation Patterns (Isohyets) (cm)

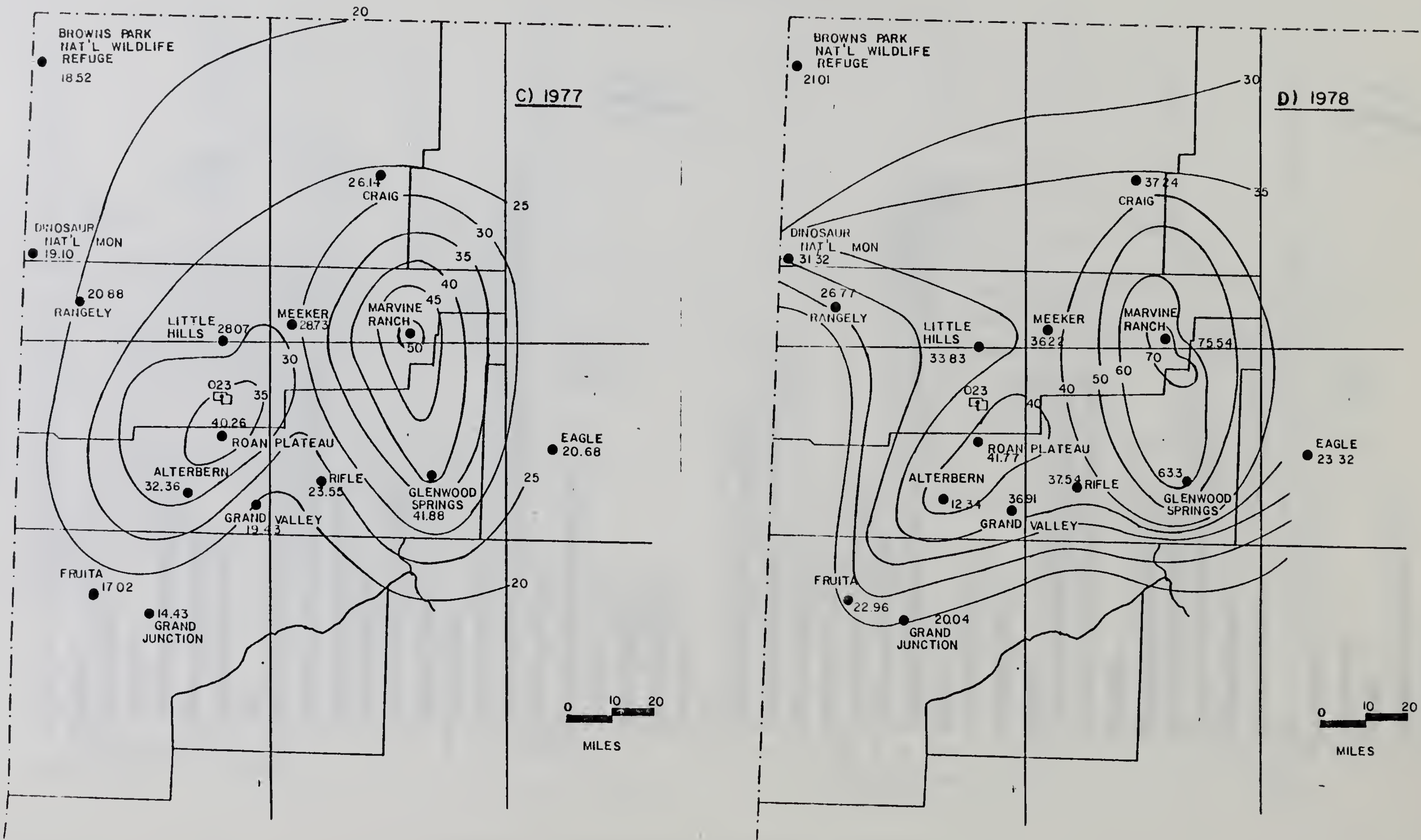
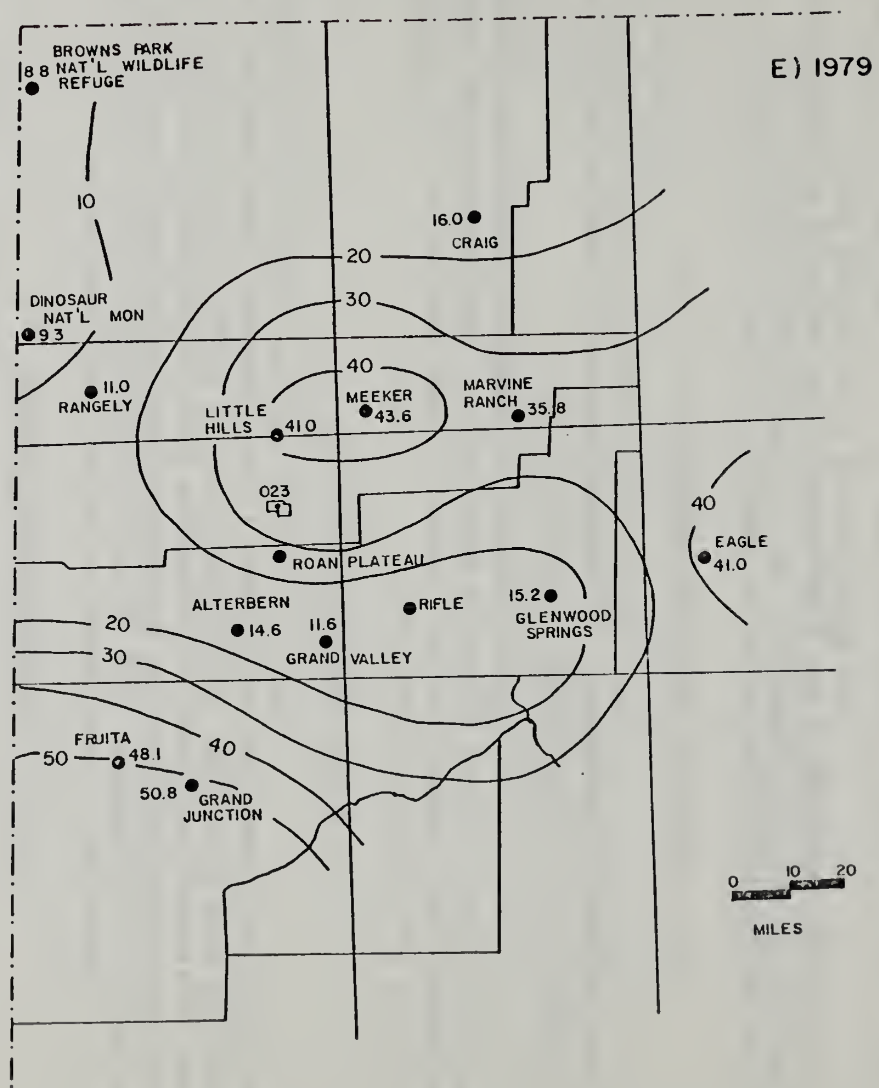


FIGURE 6.3.1-5 (Cont.)

Regional Precipitation Patterns (Isohyets) (cm)



Station AB23 have averaged 787 mb over the past five years with daily average minimums as low as 725, and maximums as high as 804 mb (Table A6.3.1-8).

6.3.2 Wind Fields

6.3.2.1 Scope

This section analyzes the wind field data collected at the meteorological tower, and Stations AB20, AB23, AD42, and AD56. Data consist of wind speed, wind direction, vertical variations in horizontal wind speed and wind direction and stability class. Wind flow patterns and stability class provide information for diffusion modeling and pollutant transport.

6.3.2.2 Objectives

The objectives of this program are:
to refine the knowledge of the wind fields in the vicinity of the C-b Tract;
to provide supporting information for air quality data analysis; and
to provide inputs for air diffusion modeling.

6.3.2.3 Experimental Design

Sampling frequency for wind data is identical to that of the air quality parameters. Parameters measured at the various stations and instrumentation used are shown in Table 6.3.2-1.

Near-surface wind fields are determined from continuous monitoring of winds at the 10 meter height. Measurements over three meteorological-tower levels along with acoustic radar provide data for vertical wind structure and stability conditions.

6.3.2.4 Method of Analysis

Analysis in this section consists of comparisons of wind field data over time and between sites. Temporal comparisons are made by comparing wind roses over several years at the given site and elevation. Seasonal differences are noted. Time-series plots are presented for winds in the Time-Series Supplements to the Development Monitoring (data) Reports and in Figure A6.3.2-1 for November 1979 through October 1980. Spatial comparisons consist of comparisons of wind roses collected at different sites.

6.3.2.5 Discussion and Results

The Environmental Baseline Final Report, Volume 3, presents some detailed analyses of wind field data. Data collected since that report have been less extensive. Analyses presented here are in the form of extensions of some of the studies previously reported. It is discussed in two parts: (a) near-surface wind fields, and (b) upper-air wind structure.

6.3.2.5.1 Near-Surface Wind Fields

Determination of predominant wind speed and

TABLE 6.3.2-1

Wind Field Parameters and Stations

Parameter	Instrument	Station
10-m horizontal wind speed	Anemometer	AB20, AB23, AD42, AD56
10-m horizontal wind direction	Vane	AB20, AB23, AD42, AD56
30-m, 60-m horizontal wind speed	Anemometer	Met Tower (AA23)
30-m, 60-m horizontal wind direction	Vane	Met Tower (AA23)
10, 30, 60-m horizontal wind direction standard deviation*	Vane	Met Tower (AA23)
ΔTemperature (60m to 10m)	ΔT Sensor	Met Tower (AA23)
Inversion height	Acoustic radar	AB20

* Computed quantity

wind direction can be made by examination of quarterly wind roses over the seasons and from year to year. Figures A6.3.2-2 through A6.3.2-12 present the quarterly wind rose plots for two years for the various meteorological stations. A summary of predominant wind direction and speed is presented in Table 6.3.2-2. The predominant wind direction at the meteorological tower is SSW and there is virtually no change from year to year. Fall and Winter quarters have lower wind speeds than Spring and Summer at the 10 meter level. However, at the 30 meter level the wind speed difference between seasonal quarters is less. As expected, wind speeds at 30 meter level are higher than at the 10 meter level.

Stations located in or near Piceance Creek Valley (AB20, AD42, AD56) tend to show downstream (drainage) flow at night (E-ESE) and upstream flow (W-WNW) in daytime for all seasons with drainage predominant.

6.3.2.5.2 Upper-Air Wind Structure

Two analyses are presented in this section: (a) acoustic radar inversion and mixing data, and (b) atmospheric stability.

(a) Inversion and Mixing Heights. Temperature inversion heights are measure by means of an AeroVironment Model 300 Acoustic Radar. The instrument was reactivated at Piceance Creek Station AB20 in November, 1977. The output of the instrument is a continuous strip chart record of reflected sound signals associated with thermal signatures; such signatures vary in character depending on whether the atmosphere is stable or unstable. The chart provides a means for determining the height of temperature inversions and mixing layers above ground level.

Figure A6.3.2-13 shows average monthly inversion heights for months of September, 1978 through August, 1979. The months are grouped by quarters to show seasonal patterns. Plots have been limited to hours with expectation of occurrence greater than 0.5. Quarterly average inversion height, onset time, breakup time, and duration are shown in Table 6.3.2-3.

For inversions aloft, the air layer between the mixing height and the top of the inversion is stable and very little diffusion of stack emissions occurs in this air layer. Any stack emissions below the mixing height are constrained by the inversion when thermal buoyancy of the plume is not great; otherwise this layer can be penetrated. Stack emissions above the inversion height will not penetrate down through the inversion.

Afternoon mixing layer height (d_{mix}) has been assessed using the upper-air study of both 1974-1975 (aircraft) and 1978 (pibal). Table 6.3.2-4 summarizes these results by month indicating the number of number of sample days, those samples for which d_{mix} was below the top of the record (normally found to be around 1800 meters for pibals), and those sample days for which d_{mix} was not obtained (due to surface inversions, neutral layers of d_{mix} above the top of the record). The monthly minimum value of d_{mix}, the maximum (recorded) and the average of the recorded values are shown. Based on these data, Figure 6.3.2-2 shows the

TABLE 6.3.2-2

Wind Rose Comparisons

Site	Quarter	Predominant Wind Direction and Speed (m/s)					
		1974-1975	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980
Tower (AA23)	Fall			SSW (1-3)	SSW (<1)	SSW (1-3)	SSW (1-3)
10 meter	Winter			SSW (1-3)	SSW (1-3)	SSW (3-5)	SW (1-3)
	Spring			SSW (5-8)	SSW (3-5)	SSW (1-3)	SSW (3-5)
	Summer			SSW (5-8)	SSW (5-8)	SSW (1-3)	SW (5-8)
Tower (AA23)	Fall	S (5-8m/sec)	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (3-5)	SSW (5-8)
30 meter	Winter	SSW (5-8)	SSW (5-8)	SSW (8-11)	SSW (3-5)	SSW (3-5)	SSW (5-8)
	Spring	SSW (5-8)	SSW (5-8)	SSW (8-11)	S (3-5)	SSW (5-8)	SSW (5-8)
	Summer	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)
AB20	Fall			E (1-3)			ESE (1-3)
10 meter	Winter						ESE (1-3)
	Spring				ESE (1-3)	ESE (1-3)	ESE (1-3)
	Summer				E (1-3)	ESE (1-3)	ESE (1-3)
AD42	Fall						E (1-3)
10 meter	Winter						ESE (1-3)
	Spring				ESE (1-3)	E (1-3)	ESE (1-3)
	Summer				E (1-3)	E (1-3)	E (1-3)
AD56	Fall						SE (1-3)
10 meter	Winter						SE (1-3)
	Spring				SE (1-3)	SE (1-3)	ESE (1-3)
	Summer				SE (1-3)	S (1-3)	ESE (1-3)

TABLE 6.3.2-3

Inversion Heights and Durations (Quarterly Averages)

Month/Year	Average Height (M)	Onset Time	Breakup Time	Duration (Hours)
Sep 78 - Nov 78	303	1720	0820	15.7
Dec 78 - Feb 79	310	1700	0940	16.7
Mar 79 - May 79	323	1800	0740	13.7
Jun 79 - Aug 79	272	1900	0720	12.3
Sep 79 - Nov 79	266	1730	0840	15.2
Dec 79 - Feb 80	273	1600	1220	20.3
Mar 80 - May 80	283	1800	0740	13.7
Jun 80 - Aug 80	314	1820	0720	13.0
Sep 80 - Nov 80	355	1700	0920	16.3

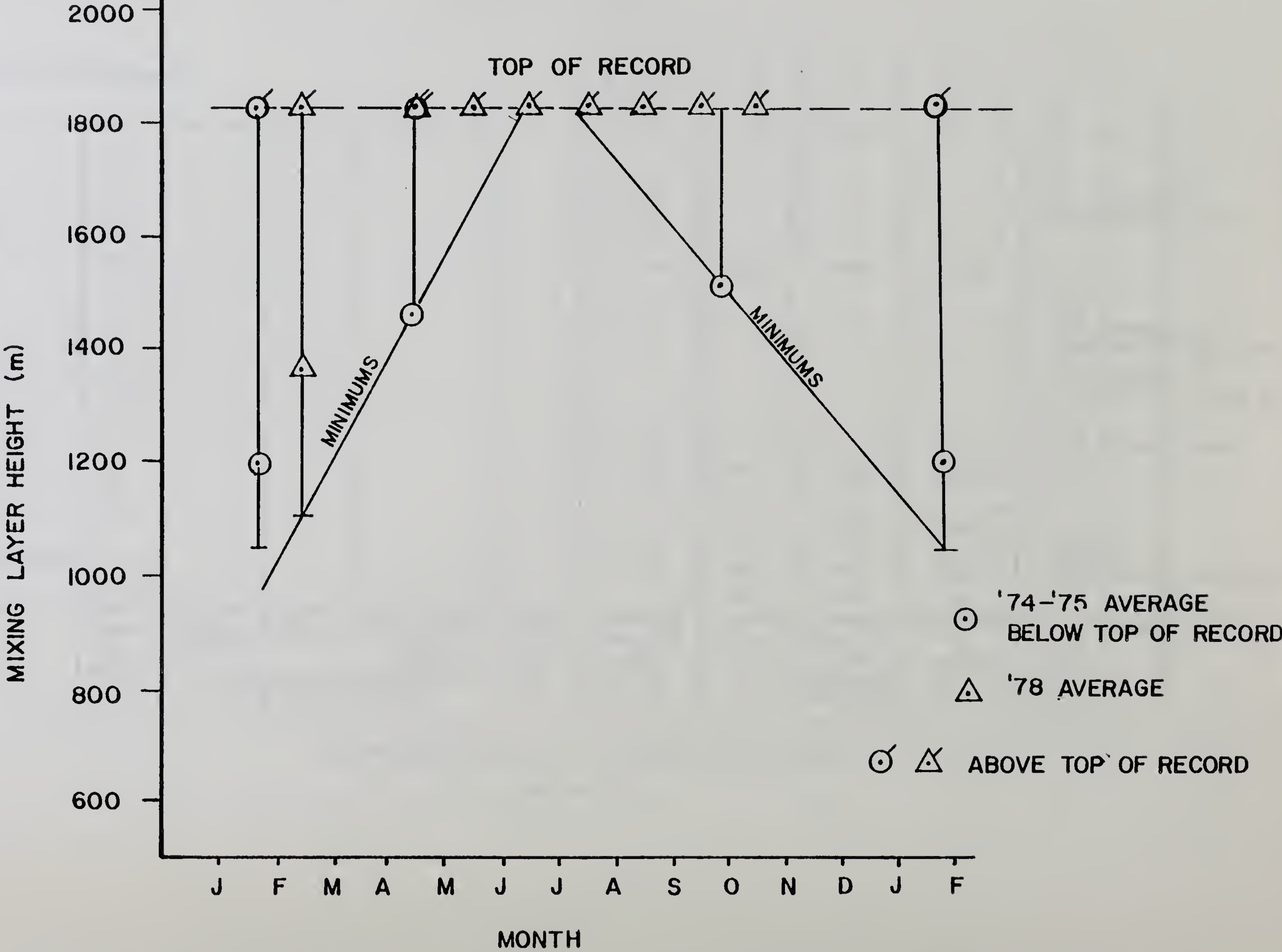
TABLE 6.3.2-4

AFTERNOON MIXING LAYER HEIGHT (d_{mix}) (meters above surface)

Month/Year	Total Number of Sample Days	No. of Sample Days d_{mix} Not Obtained Because of				No. of Sample Days When d_{mix} Obtained	d_{mix} (meters)			Comments
		Surface Inversion Exists	Neutral Layer	Unstable Surface Layer with Neutral Above	d_{mix} Above Top of Record*		Minimum Value	Maximum Value (below top of record)	Average of All Values	
October 1974	8				6	2	1494	1524	1509	
January-February 1975	13	1	1		6	5	1037	1494	1199	2 very weak not included in average
April 1975	13				12	1	1463	1463	1463	
July 1975	12				12					
February 1978	11		2		7	2	1100	1650	1375	
March 1978	6	1			5					1 day of partial data
April 1978	8				8					
May 1978	10				9					1 very weak d_{mix} at 920 m not counted
June 1978	12				11					1 very weak d_{mix} at 210 m not counted
July 1978	11	1	1		9					
August 1978	10			2	7	1	3300	3300	3300	
September 1978	8	2			6					
October 1978	11	1			8	2				Weak d_{mix}'s at 450 m 200 m not counted
November 1978	5	2		1	1					

*Top of Record Usually Near 1800 m

FIGURE 6.3.2-2
AFTERNOON MIXING LAYER HEIGHT
VS.
TIME OF YEAR



variations in the d_{mix} with time of year, with minima shown to occur in winter and maxima in summer. A winter average minimum of 1500 meters is judged to be representative for this time of year; summer averages were above the top of the record near 1800 meters.

(b) Stability Class Study. Monthly average stability classes have been derived from hourly stability class data. The hourly stability classes are based on delta temperature measurements from the 60-meter to the 10-meter levels on the meteorological tower. Pasquill-Gifford stability classes were determined from the slope of the temperature-altitude curve (dT/dz) and adjusted for wind speed by the method described in the Baseline Report, Volume 3. Monthly averages by hour from the period from November, 1976 through October, 1980 are shown in Table 6.3.2-5 for the months containing more than 50 percent of the data. Unstable, neutral, and stable classes are indicated by variable shading. Comparison of these data with the baseline period (November, 1974 through October, 1976) shows similar patterns for the broad classifications of unstable, neutral, and stable classes. The period for November, 1976 through May, 1977 is very similar to the same months in the baseline years. However, 1978 to 1980 data for January-March and July-September tended to reflect a shift in stability class toward the stable end of the scale (toward Class F) by one Pasquill-Gifford stability class for most of the monthly averages by hour. No clear explanation can be identified for this.

Table 6.3.2-6 presents the percentage of hours in each stability class for each month. The baseline data are included for comparison. This table also reflects the shift to the more stable classes for 1978-1980.

Typically the hours between 0900 and 1900 are unstable. Nighttime and early mornings are typically stable.

Atmospheric stability as discussed above is based on the meteorological-tower temperature difference. For high altitude pollutant releases, atmospheric stability should be assessed at the effective stack height of the plume; this height is dependent on individual stack height and plume buoyancy. A height of 1000 feet has been selected as representative and the four quarters of aircraft flights of 1974-1975 at (normally) 15 flight-days per quarter and four flights per flight-day have been reexamined and summarized on Table A6.3.2-1. For all flights the only Pasquill-Gifford stability classes existing were D's and E's at the 1000-foot height and for at least another 1000 feet above this.

6.3.2.6 Conclusions

Conclusions supported by the analysis of wind-field data are:

1. Predominant wind direction at the meteorological tower site on Tract is SSW; this has not changed over time.
2. Predominant wind direction in and near Piceance Creek is downstream (from east and southeast) over most of the nighttime and early morning. Daytime direction reverses to upstream flow.

Table 6.3.2-5

AVERAGE HOURLY STABILITY CLASSES (1978 - 1980)

SOURCE: Temperature differences between 60 meter and 10 meter on the Met Tower (Adjusted for Wind Speed)

Month	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Nov. 1978	E	E	E	E	E	E	E	E	E	E	E	E	D	D	D	D	E	E	E	E	E	E	E	E	E
Dec.	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Jan. 1979	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Feb.	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Mar.	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	D	D	E	E	E	E	E	E	E
Apr.	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
May	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
June	E	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E
July	F	F	E	E	F	F	F	E	E	E	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
Aug.	F	F	F	F	F	F	F	F	E	D	C	D	D	C	D	D	D	D	E	E	E	F	E	F	E
Sept.	F	F	F	F	F	F	F	F	E	D	C	C	C	C	C	C	D	D	E	E	F	F	F	F	E
Oct.	E	E	E	E	F	F	F	F	E	D	C	C	C	D	D	D	D	D	E	E	E	E	E	E	E
Nov.	E	E	F	F	E	E	E	F	F	E	D	D	E	E	D	D	D	E	E	E	E	E	E	F	E
Dec.	F	E	E	F	E	E	F	F	E	E	E	E	E	D	D	D	E	E	E	E	E	E	E	E	E
Jan. 1980	E	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E
Feb.	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	D	D	E	E	E	E	E	E	E	E
Mar.	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E
Apr.	E	E	E	E	E	E	E	E	D	D	D	D	C	D	D	D	D	D	E	E	E	E	E	E	E
May	E	E	E	E	E	E	E	D	D	C	C	C	C	C	C	D	D	D	D	E	E	E	E	E	D
June	F	F	F	F	F	F	F	D	D	C	C	C	C	C	C	C	C	D	D	E	E	E	E	E	D
July	E	E	E	E	E	E	E	D	D	D	C	C	C	C	C	C	D	D	D	E	E	E	E	E	E
Aug.	F	F	F	F	E	E	E	D	D	C	C	C	C	C	C	C	C	D	D	E	E	E	E	E	D
Sept.	F	F	F	F	E	E	E	E	D	C	C	C	C	C	C	C	C	D	E	E	E	E	F	F	D
Oct.	E	E	E	E	E	E	E	E	D	C	C	C	C	C	C	C	D	D	E	E	E	E	E	E	E

AVERAGE HOURLY STABILITY CLASSES (1980 -

SOURCE: Temperature differences between 60 meter and 10 meter on the Met Tower (Adjusted for Wind Speed)

Month	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Nov. 1980	E	E	E	E	E	E	E	E	E	D	C	C	C	C	C	C	D	D	E	E	E	E	E	E	D

* Partial data only, less than 100% but more than 50%

1 Missing data

Key:
- Unstable Class
- D Neutral
- Stable Class

TABLE 6.3.2-6

METEOROLOGICAL SUMMARY: STABILITY CLASS FREQUENCIES (%)

SOURCE: Meteorological Tower (10m to 60m)

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1974 November[2]	1974 December[2]	1975 January	1975 February	1975 March	1975 April	1975 May	1975 June	1975 July[3]	1975 August	1975 September	1975 October	Annual Mean
A	<-1.9			8.3	1.0	1.1	12.0	7.4	8.6	0.0	2.4	5.8	8.1	6.1[4]
B	-1.9 to -1.7			5.5	4.4	10.3	23.5	30.6	25.6	85.7	19.3	23.4	20.6	18.1
C	-1.7 to -1.5			4.1	2.4	16.3	6.9	9.3	6.9	14.3	6.1	5.0	5.7	7.0
D	-1.5 to -0.5			33.0	43.4	60.9	36.3	30.0	27.0	0.0	25.8	13.4	28.3	33.1
E	-0.5 to +1.5			33.3	36.8	11.4	18.1	12.1	18.0	0.0	17.3	24.4	18.6	21.1
F	>1.5			15.8	12.0	0.0	3.2	10.6	13.9	0.0	29.1	28.0	18.7	14.6
	TOTAL PERCENTAGE			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1975 November	1975 December	1976 January	1976 February	1976 March	1976 April	1976 May	1976 June	1976 July	1976 August	1976 September	1976 October	Annual Mean
A	<-1.9	15.6	18.8	24.9	13.8	19.4	9.5	17.5	4.6	10.3	7.4	13.1	13.6	14.0
B	-1.9 to -1.7	19.7	20.7	21.3	22.1	27.0	21.7	26.3	17.4	30.5	18.4	25.5	20.6	22.6
C	-1.7 to -1.5	6.9	7.4	5.6	7.7	7.9	9.7	6.0	10.0	5.6	6.7	6.1	5.6	7.1
D	-1.5 to -0.5	23.7	21.5	16.6	35.7	28.7	35.2	21.0	32.7	14.1	27.6	17.5	17.9	24.4
E	-0.5 to +1.5	22.9	23.5	21.0	13.8	15.6	17.0	15.6	17.6	19.5	23.0	20.7	21.2	19.3
F	>1.5	11.2	8.1	10.6	6.9	1.4	6.9	13.6	17.6	20.0	16.9	17.1	21.1	12.6
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1976 November	1976 December	1977 January	1977 February	1977 March	1977 April	1977 May	1977 June	1977 July	1977 August	1977 September	1977 October	Annual Mean
A	<-1.9	18.6	12.3	18.0	12.9	12.9	12.9	5.9						13.3
B	-1.9 to -1.7	19.8	20.7	18.5	27.7	21.6	29.6	13.3						21.6
C	-1.7 to -1.5	4.3	7.1	6.8	7.3	7.9	8.1	9.2						7.2
D	-1.5 to -0.5	12.5	16.2	20.9	12.1	30.1	19.0	46.6						22.5
E	-0.5 to +1.5	27.4	23.7	25.4	26.3	19.3	18.1	17.8						22.6
F	>1.5	17.4	20.0	10.4	13.7	8.2	12.6	7.2						12.8
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0						100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1977 November[5]	December[5]	1979 January	February[3]	March[3]	April[5]	May[5]	June[5]	July[3]	August[3]	September[3]	October	Annual Mean
A	<-1.9			0.7	0.3	0.3				0.0	0.2	0.0		
B	-1.9 to -1.7			0.3	2.1	0.5				2.3	6.1	2.6		
C	-1.7 to -1.5			4.4	2.9	1.9				5.9	5.7	2.6		
D	-1.5 to -0.5			52.0	48.0	47.4				43.2	35.6	40.1		
E	-0.5 to +1.5			28.2	32.9	24.8				19.5	22.5	23.5		
F	>1.5			14.4	13.8	25.1				29.1	29.9	31.2		
	TOTAL PERCENTAGE			100.0	100.0	100.0				100.0	100.0	100.0		

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1978 November	December	1979 January	February	March	April	May	June	July	August	September	October	Annual Mean
A	<-1.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	1.3	1.0	1.2	1.8	0.5
B	-1.9 to -1.7	0.0	0.2	0.0	0.0	0.0	0.1	0.5	0.6	4.7	7.8	9.4	5.3	2.4
C	-1.7 to -1.5	0.1	0.0	0.0	0.0	0.0	2.2	3.6	1.8	1.8	4.5	5.8	4.3	2.0
D	-1.5 to -0.5	20.9	26.8	16.4	19.4	24.4	46.3	42.3	41.6	24.3	21.6	18.3	26.9	27.4
E	-0.5 to +1.5	53.6	51.5	60.5	54.4	57.6	29.1	33.7	27.0	30.4	31.4	20.4	29.0	39.8
F	>1.5	25.4	21.5	23.1	26.2	17.9	22.3	19.9	28.6	37.5	33.7	44.9	33.7	27.9
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1979 November	December	1980 January	February	March	April	May	June	July	August	September	October	Annual Mean
A	<-1.9	.5	.6	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	1.3	1.7	0.4
B	-1.9 to -1.7	.7	.3	.4	.3	.4	5.4	6.6	9.0	9.8	13.7	11.9	13.7	6.0
C	-1.7 to -1.5	.7	.1	.3	0.0	.1	4.0	10.1	13.0	10.8	11.4	9.2	9.6	5.8
D	-1.5 to -0.5	17.8	22.5	48.3	28.5	47.3	39.6	42.0	28.9	26.8	27.5	25.8	23.2	31.5
E	-0.5 to 1.5	49.5	37.4	34.0	47.3	39.0	31.0	25.1	22.7	24.0	21.1	23.2	22.3	31.4
F	>1.5	30.8	39.1	17.0	23.9	13.2	20.0	16.2	26.1	28.4	26.3	28.6	29.5	24.9
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Adjusted for wind speed

[2] Data are suspect and, therefore, not included

[3] Partial data

[4] Averaged from January-October, excluding July

[5] Missing data

[6] Data for July and August not available for this report

Conclusions supported by analyses from the addition of 1980 data to previously reported data are:

1. Monthly mean temperatures and variations in 1980 are consistent with the values from the past four years since the Baseline Report.
2. The maximum growing season for the past five years was recorded in 1980 (151 days, May 12 to October 15).
3. Direct solar radiation for 1980 was within the range of previous years showing no substantial variations.
4. Annual means for relative humidity have been consistent throughout the six-year study period.
5. Precipitation for Station AB23 has a six year (1975 - 1980) annual average of 37.90 cm ranging from 35.8 cm in 1976 to 45.0 cm in 1975. Annual precipitation for 1980 was 36.7 cm.

7.0 NOISE

7.1 Introduction and Scope

The environmental noise program conducted since baseline is not required under the Lease but was requested by the Oil Shale Supervisor. General background noise levels were sought on the Tract and surrounding vicinity prior to Tract development. Monitoring of those levels was reinitiated in February, 1978 at the three sites shown in Figure 7.1.1-1 to determine the effects of Tract development on noise levels and has continued through the development period.

7.2 Environmental Noise

Occupational noise exposure is treated in Section 7.8 of Volume 1 of this report. Aspects of environmental noise treated here deal with traffic and Tract-generated noise levels.

7.2.1 Traffic Noise

7.2.1.1 Scope

The traffic noise study was originated during baseline. Measurements were made one working day per month for approximately one hour at each of 14 locations over a 14-month period starting in September 1975. Measured noise levels (A weightings) above background at two locations along Piceance Creek Road were always made in the presence of passing vehicles. The noise analysis contained in the Final Baseline Report indicated an average level at a station on Piceance Creek Road near Hunter Creek to be 53 dbA which was exceeded ten percent of the time.

On the basis of low noise levels existing during baseline as indicated in the Final Baseline Report, it was felt that continued discrete measurements were warranted at only two of the original 14 locations. Stations NA02 and NA09 are located to indicate traffic noise levels associated with development.

7.2.1.2 Objective

The objective of noise level measurement is to measure potential increases in traffic noise levels due to development.

7.2.1.3 Experimental Design

Discrete traffic noise measurements are made one per day per week in the presence of passing vehicles at Stations NA02 and NA09 (Figure 7.1.1-1) along Piceance Creek Road and on the access road at the Tract boundary, respectively. The General Radio 1565 Sound Level Meter is used to measure peak noise levels at A weightings. Background levels are obtained the same day at A, B, and C weightings.

FIGURE 7.1.1-1

NOISE ENVIRONMENTAL MONITORING NETWORK

● TRAFFIC NOISE STATION - PEAK MEASUREMENT - 1 DAY/WEEK

■ TRACT NOISE SURVEILLANCE - CONTINUOUS - EVERY 6th DAY

7.2.1.4 Method of Analysis

At each of the two stations, peak noise levels are measured weekly. Four weekly composite peak measurements are then averaged.

7.2.1.5 Discussion and Results

Figure 7.2.1-1 shows a time plot of peak traffic noise levels and background levels for the C-b Tract. The highest noise level of 91 dbA occurred on June 30, 1978 at Station NA02 from a passing semi-trailer truck; the background noise level at that time was 44 dbA. The peak noise level indicated in the Final Baseline Report was 83 dbA from a road scraper in July 1976. The percent of monthly peaks exceeding this level was 15 percent in 1978, 65 percent in 1979, and 67 percent in 1980. On the average, the monthly peaks during the development period remain nine dbA higher than the peaks measured during baseline. The increase is most likely due to development activity.

7.2.2 Tract Noise

7.2.2.1 Scope

During the initial phases of development much activity occurs near the northern boundary of the Tract. Thus a noise monitoring site in the vicinity of operations is most appropriate for monitoring noise levels on the Tract due to early development.

7.2.2.2 Objectives

The objectives of the Tract noise study are to evaluate increases in Tract noise due to Tract development, and to demonstrate compliance with State noise regulations.

State noise standards for an industrial zone are as follows in terms of maximum allowable noise levels:

Steady:	80 db(A) 7am to next 7pm
	75 db(A) 7pm to next 7am
15 min. in any one hour:	90 db(A) 7am to next 7pm
Periodic, impulsive, shrill:	75 db(A) 7am to next 7pm
	70 db(A) 7pm to next 7am

These standards apply within 25 feet of the property line. The Tract has not been classified industrial at this time.

7.2.2.3 Experimental Design

Continuous noise measurements are made at Station NB15 (Figure 7.1.1-1) on the northern boundary of the Tract for 24 hours every sixth

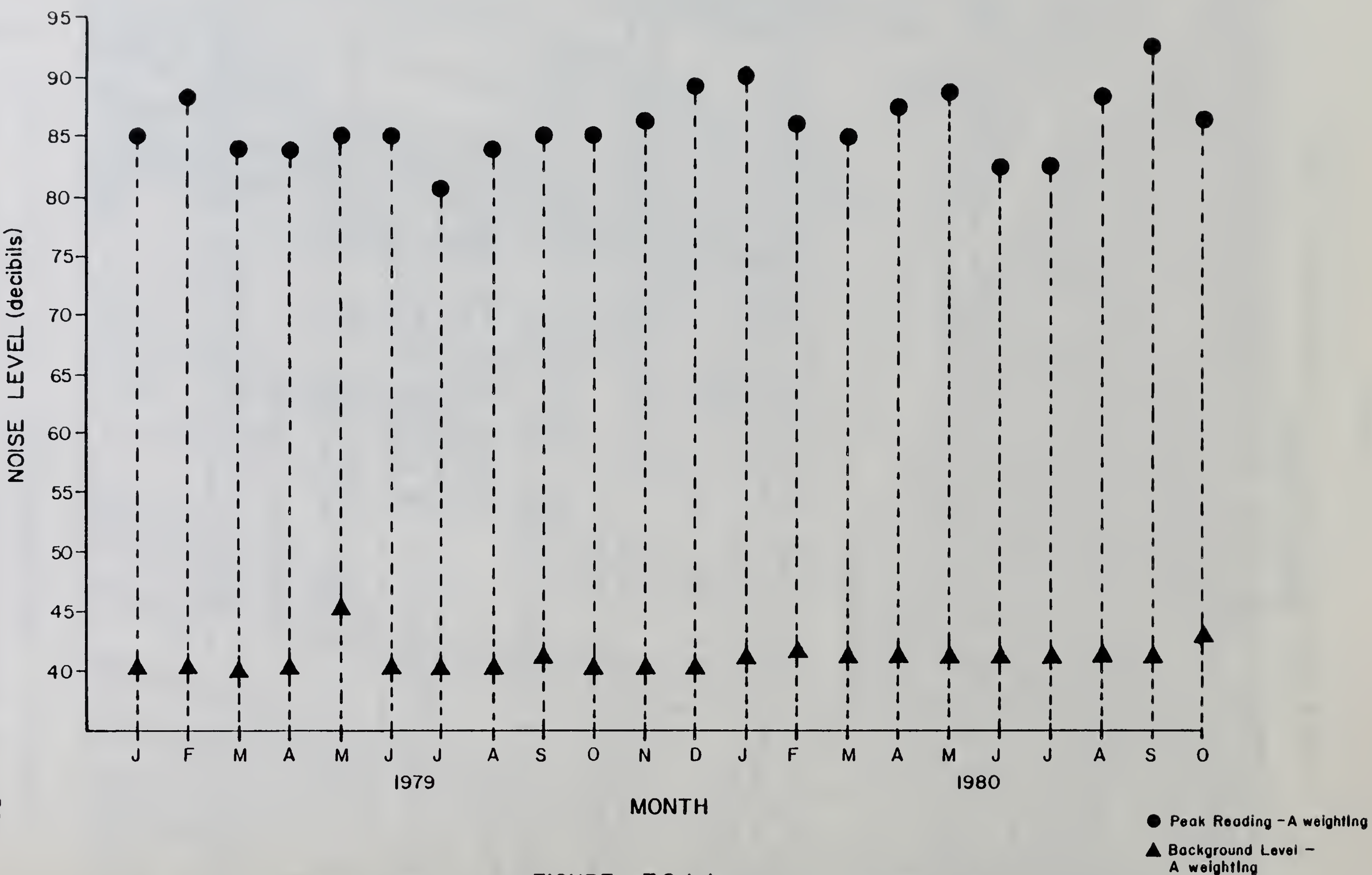


FIGURE 7.2.1-1
TRACT C-b PEAK TRAFFIC N-.SE READINGS
(1979-1980)

day. The sensor recording system consists of the following B & K instruments:

Model 2203	Precision Sound Level meter (SLM) with 0.5" microphone
Model 4230	Portable Acoustic Calibrator
Model UA 0393	Microphone Rain Cover
Model UA 0381	Wind Screen with Spikes
Model UA 0308	0.5" Dehumidifier
Model 2306	Portable Graphic Level Recorder

In this model the sound level meter is coupled to the battery operated linear recorder for 24 hours of unattended all-weather operations at an A-weighting.

The sound level meter is calibrated before each day's use with its portable acoustic calibrator to $\underline{+}0.25$ db accuracy at 93.6 db, 1 kHz. The linear recorder for a range is calibrated before and after each day's use. Thus any drifts are readily apparent. Time references are noted before and after operation.

7.2.2.4 Method of Analysis

Twelve-hour peaks (7am - 7pm and 7pm - 7am) are reported along with averages and background levels for each day of observations. Figure 7.2.2-1 presents the peak 12-hour Tract noise levels.

7.2.2.5 Discussion and Results

The peak Tract noise level reading of 83 dbA occurred on the first day of monitoring in February 1978; that peak did not exceed 90 dbA for 15 minutes in any hour. All other readings through December 1980 were below 80 dbA from 0700 to 1900 and below 75 dbA from 1900 to 0700. The arithmetic average decibel level during the development period for both 12-hour periods was less than 44 dbA.

7.2.3 Conclusions

Monthly peak noise levels and background levels during the development period exceed those of the baseline period by an average of nine dbA. This increase is most likely due to development activity.

Noise levels in the Tract area due to development activities have, for the most part, remained low. Average levels of neither 12-hour period appear to have increased significantly over the development period.

Compliance with State noise standards for an industrial zone was achieved; the Tract is not classified industrial at this time.

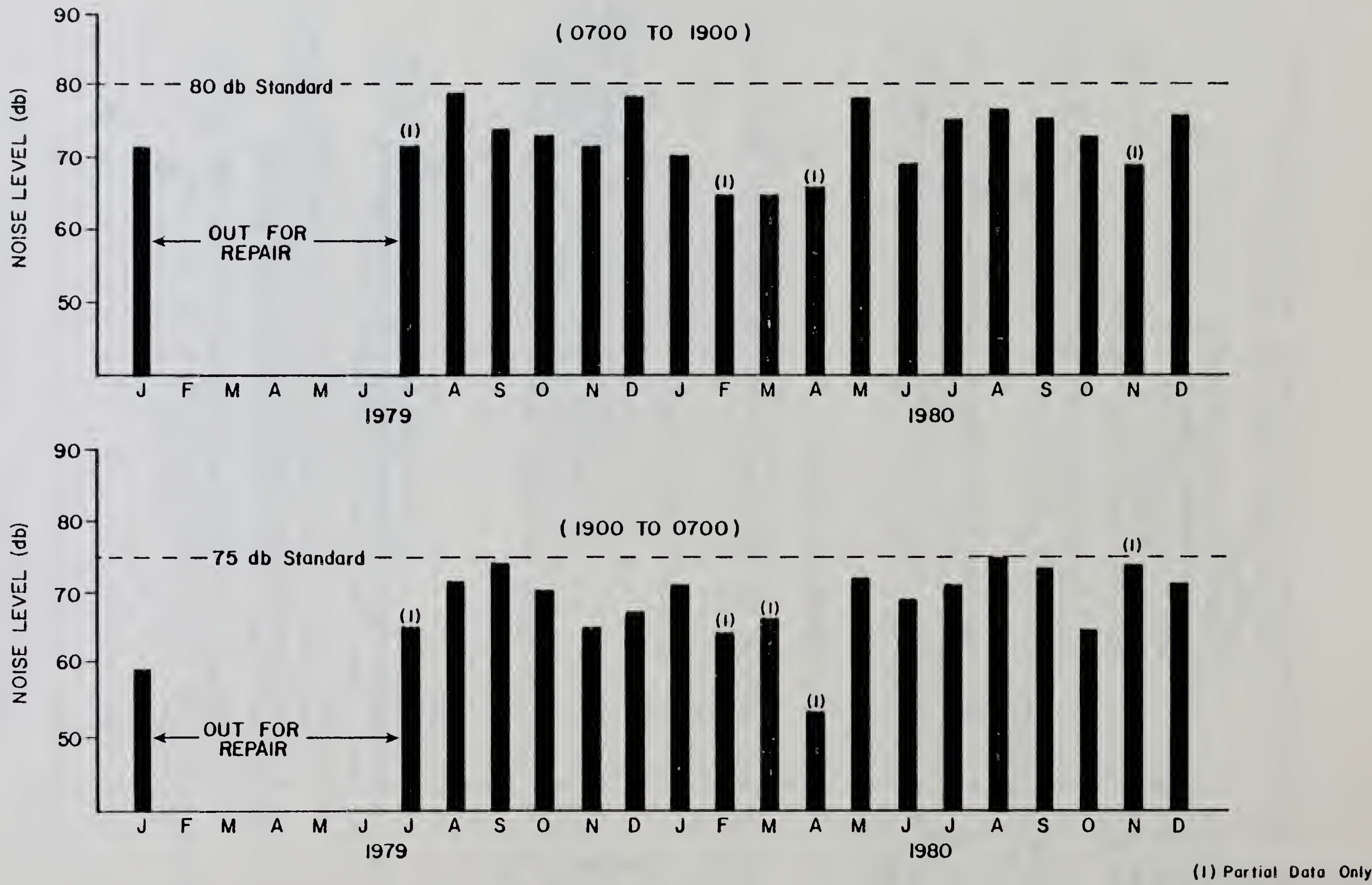


FIGURE 7.2.2-1
TRACT C-b HOURLY PEAK READINGS (db)
FOR 79'-80' AT SITE NB15

8.0 BIOLOGY

8.1 Introduction and Scope

The goal of the biological monitoring program is to continue evaluation of biotic conditions and identify interactions with abiotic conditions in the Tract C-b ecological systems. The majority of monitoring parameters are those that provide information relative to early warning signals of change. The use of control and development sites permits the monitoring of long-term trends at affected and unaffected sites and the analysis of any corresponding differences developing over time at these sites. Monitoring sites are shown in Exhibit C.

8.2 Big Game: Mule Deer

Big game refers primarily to mule deer, since they are the only large mammals common to the C-b area apart from domestic cattle. Intensive studies of mule deer are justified since deer are a major herbivore of ecological importance and a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure.

Monitoring of mule deer attempts to show the significance of Tract C-b to their survival. This is accomplished through analysis of the following variables: 1) deer pellet group densities, 2) browse production and utilization, 3) migrational patterns and phenology, 4) road kills, 5) natural mortality, and 6) age-class composition. Study transect locations and sample sizes are based on baseline experience.

8.2.1 Deer Pellet Group Densities

8.2.1.1 Scope

Pellet group counts were conducted along 27 permanent transects. Twelve transects are located on Tract; nine are located on Big Jimmy Ridge, approximately one and one-half miles to the west; and six are located north of Piceance Creek, approximately one and one-half miles to the north.

8.2.1.2 Objectives

The objectives of pellet group studies are to evaluate differences on a site specific basis and over time in order to make inferences regarding the possibility of positive or negative effects on deer due to development activities.

8.2.1.3 Experimental Design

Transects were located using a stratified random design, except at certain development locations where the placement of a transect was predetermined. Two strata (habitat types) were sampled: pinyon-juniper woodland and chained rangeland. Fifteen transects were located in the chained rangeland habitat type and twelve transects were located in the

~~pi~~nyon-juniper woodland. All pellet group transects have a BA computer-code notation. Their exact locations are shown on the jacket map. Plots were raked in the fall and the pellet groups were counted in the spring.

8.2.1.4 Method of Analysis

All statistical analyses for the 1979-80 period are standard parametric procedures including the analysis of variance, t-test, product-moment correlation coefficient, and others. Such procedures as a priori comparisons and one-tailed tests are explained where appropriate.

8.2.1.5 Discussion and Results

Deer pellet count data for the 1979-80 period (Table 8.2.1-1) were examined for indications of impacts due to development. Transects BA20 and BA16 seemed relatively low in count and, therefore, were singled out for analysis. Transect BA20 is located east of Cottonwood Gulch in the area where the sprinkler system was installed. While sprinkling did not occur until May 27, 1980 sprinkler pipe was on the ground throughout the 1979-80 winter period when deer were present in the C-b area. Transect BA16 is located next to the main access road leading into Tract C-b. Because of potential disturbances at these two sites, statistical tests were performed to test the hypothesis that deer pellet group densities at these two sites dropped below values which are to be expected given the natural variation within the ecosystem. The null hypothesis tested was that there is no difference in mean pellet group densities between 1980 and previous years at the two development locations (H_o: $\overline{X}_{80} = \overline{X}_{77}, \overline{X}_{78}, \overline{X}_{79}$ at both BA20 and BA16).

In the design of the analysis it was considered necessary to take into account two important sources of variation: 1) within-transect variance, and 2) the variation in deer population levels from year to year. To accomplish this, a one-way ANOVA (analysis of variance) was performed on pellet group data obtained since the winter of 1976-77 (a total of 95 transects of 20 quadrats each). The MSE (mean square error) was extracted from the ANOVA to provide an estimate of the overall within-transect variance. This 4-year data set was then adjusted for yearly differences in deer population levels. In doing this, the assumption was made that yearly differences in herd size are reflected in the overall yearly mean pellet count, and that adjusting overall yearly means by addition or subtraction, setting them equal to a reference year (1979-1980 in this case), would adjust for natural fluctuations in herd size without obscuring relative difference in local deer distributions. This procedure is outlined in Table 8.2.1-2, along with details of subsequent statistical tests. To evaluate whether mean pellet group densities at development locations were outside an expected range given no impact, a Scheffe's test for multiple contrast comparisons was used (Zar 1974). As mentioned, the MSE was obtained from the ANOVA performed on all pellet group data obtained to date. The degrees of freedom for the Scheffe's test, however, were based on only the four means being tested. As stated in Table 8.2.1-2, impacts could not be detected at BA20 or at BA16. These findings can be further elaborated as follows: the mean values at locations BA20 and BA16 during 1979-80 would have had to drop outside the ranges 6.35 $\pm$ 2.13 (4.22 and 8.48) and 3.36 $\pm$ 2.13 (1.23 and 5.49)

Table 8.2.1-1 Deer pellet group densities 1979-80.

Transect	Mean pellet groups per acre ± SE (n)*
Chained pinyon-juniper:	
BA17	575 ± 96.2 (20)
BA18	495 ± 80.0 (20)
BA25	745 ±106.5 (20)
BA20	470 ± 67.7 (20)
BA21	750 ±110.9 (20)
BA23	480 ± 94.5 (20)
BA01	415 ± 53.0 (20)
BA02	480 ± 78.7 (20)
BA03	310 ± 46.4 (20)
BA04	535 ± 83.1 (20)
BA05	475 ± 58.0 (20)
BA06	195 ± 33.6 (20)
BA07	155 ± 26.6 (20)
BA08	230 ± 37.8 (20)
BA09	255 ± 39.4 (20)
Pinyon-juniper woodland:	
BA19	435 ± 77.9 (20)
BA26	225 ± 36.9 (20)
BA27	390 ± 67.2 (20)
BA16	226 ± 58.7 (19)
BA22	340 ± 57.3 (20)
BA24	305 ± 50.0 (20)
BA10	355 ± 50.0 (20)
BA11	320 ± 56.0 (20)
BA12	380 ± 60.5 (20)
BA13	435 ± 77.6 (20)
BA14	790 ± 70.3 (20)
BA15	885 ±135.4 (20)

* n = number of 0.01 acre plots sampled

Table 8.2.1-2. Impact analysis of deer pellet group data. Transects BA20 and BA16 are examined for development related impacts during the 1979-80 period. Transect means are expressed as pellents/quadrat. See text for details.

Year of spring counts	Within-year means of all pellet transects	Amount of difference from 1980 mean	Transect means (adjusted pre-development means in parentheses)	
			BA20	BA16
1977 (Control)	5.49	+ 1.47	(8.28)	(2.78)
1978 (Control)	3.36	- .66	(6.01)	(3.76)
1979 (Control)	2.42	- 1.60	(4.75)	(3.55)
1980 (Development)	4.02		4.70	2.26

EMS from ANOVA = 8.24. DF among = 94; DF error = 1802 (i.e., 95 transects, of 20 quadrats each, were examined for within-transect variance).

Multiple Contrast Comparisons (Scheffé's Test):

Transect	Contrast	SE	S	Sα	Conclusion
	Control (77, 78, 79) — Development (80): $\frac{\overline{X}_{77}+\overline{X}_{78}+\overline{X}_{79}}{3} - \overline{X}_{80}$	$\sqrt{MSE(\frac{1}{3n}+\frac{1}{n})}$	$\frac{\text{Contrast}}{\text{SE}}$	$\sqrt{(K-1)\,F_{.05}\,(3,76)}$ *	
BA20	$\frac{8.28+6.01+4.75}{3} - 4.70 = 6.35 - 4.70 = 1.65$	$\sqrt{8.24(\frac{1}{60}+\frac{1}{20})} = 0.741$	$\frac{1.65}{0.741} = 2.23$	$\sqrt{(3)(2.74)} = 2.87$	S<Sα ∴ no impact
BA16	$\frac{2.78+3.76+3.55}{3} - 2.26 = 3.36 - 2.26 = 1.10$	$\sqrt{8.24(\frac{1}{60}+\frac{1}{20})} = 0.741$	$\frac{1.10}{0.741} = 1.48$	$\sqrt{(3)(2.74)} = 2.87$	S<Sα ∴ no impact

* degrees of freedom based on the 4 means at each development location.

respectively to be judged outside a range of variation that can be attributed to the natural variation within the ecosystem.

8.2.1.6 Conclusions

Pellet group densities were higher in the 79-80 period than the 78-79 period. Developmental activities on Tract C-b have not significantly affected deer pellet group densities within the study area.

8.2.2 Browse Production and Utilization

8.2.2.1 Scope

Production and browse utilization (by deer) studies of bitterbrush and mountain mahogany were conducted along 23 transects, representing a total of 249 shrubs sampled. Of this total, 219 of the shrubs sampled were bitterbrush and 30 were mountain mahogany.

8.2.2.2 Objectives

The main objective of browse production and utilization studies is to quantify natural variation in range condition over time in order to permit evaluation of site specific changes which might be due to impacts or to mitigation.

8.2.2.3 Experimental Design

The experimental design of browse production and utilization studies is identical to that of pellet group density studies in that the same transects are used in each case. Production-utilization studies, however, make use of fewer of the BA-designated transects, and generally only ten stations along a transect are sampled. Methods consist of measuring lengths of current annual growth in the Fall (10 shoots per shrub), marking main stems for relocation, and measuring what remains of the current annual growth in the Spring.

8.2.2.4 Method of Analysis

All statistical analyses for the 1979-80 period are standard parametric procedures, including the analysis of variance, t-test, product-moment correlation coefficient, and the Student-Newman-Keuls (SNK) multiple-range test (Zar 1974).

8.2.2.5 Discussion and Results

Trends in production and utilization of bitterbrush over the past four years are shown in Figure 8.2.2-1. Production utilization estimates for 1979-80 and production estimates for 1980 are shown in Tables 8.2.2-1 and 8.2.2-2 respectively.

An analysis was performed on 1980 browse production (measured during August), which compared shrubs sprinkled with mine water effluent, to "control" shrubs located nearby. Transects BA20 and 32 (watered)

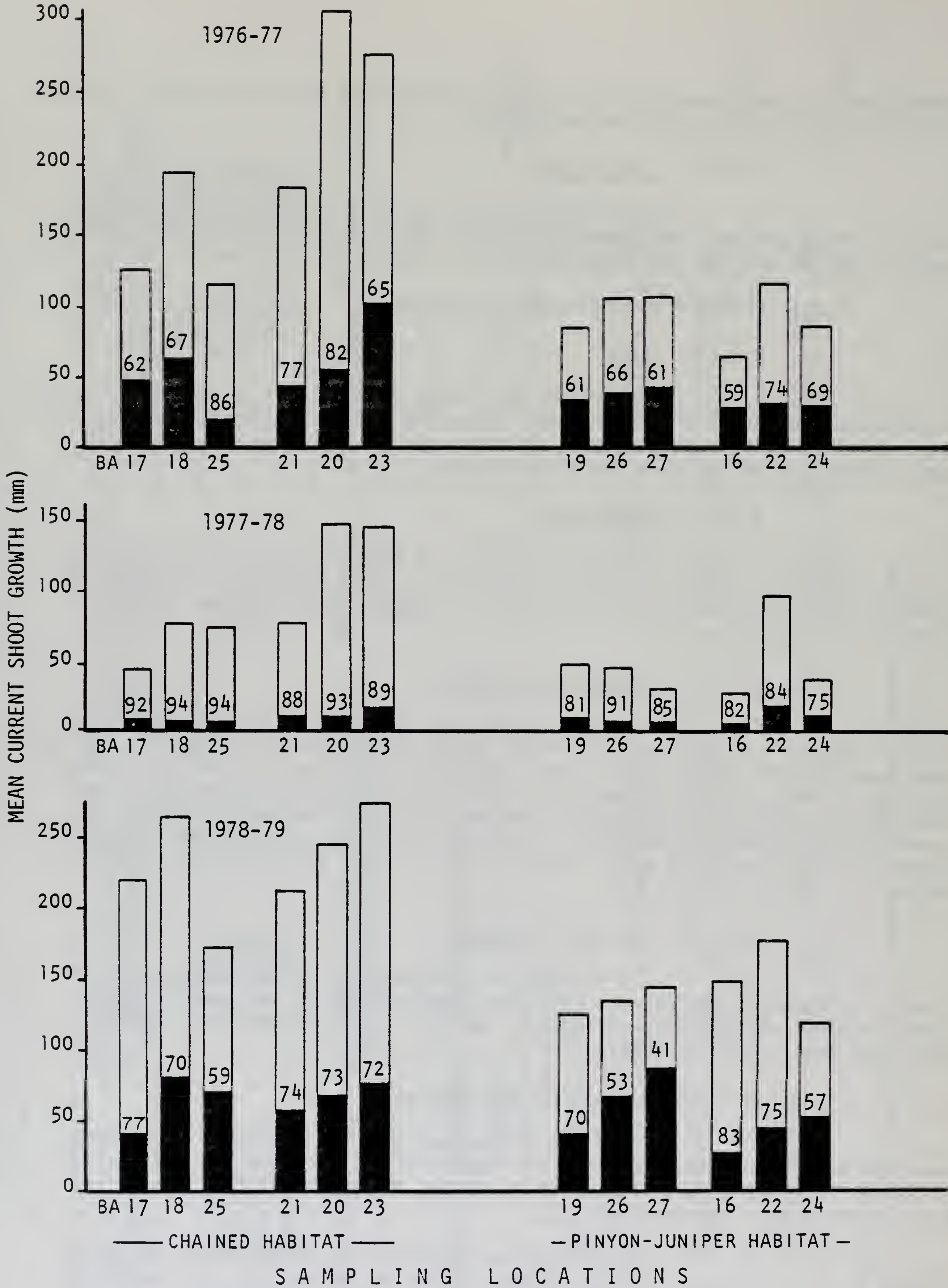


Fig. 8.2.2-1. Trends in production and utilization of bitterbrush. Bars represent mean current shoot growth. Shaded areas represent the current growth remaining after winter browsing. Numbers inside bars represent the percent of current shoot growth consumed by deer. Transect numbers are below bars.

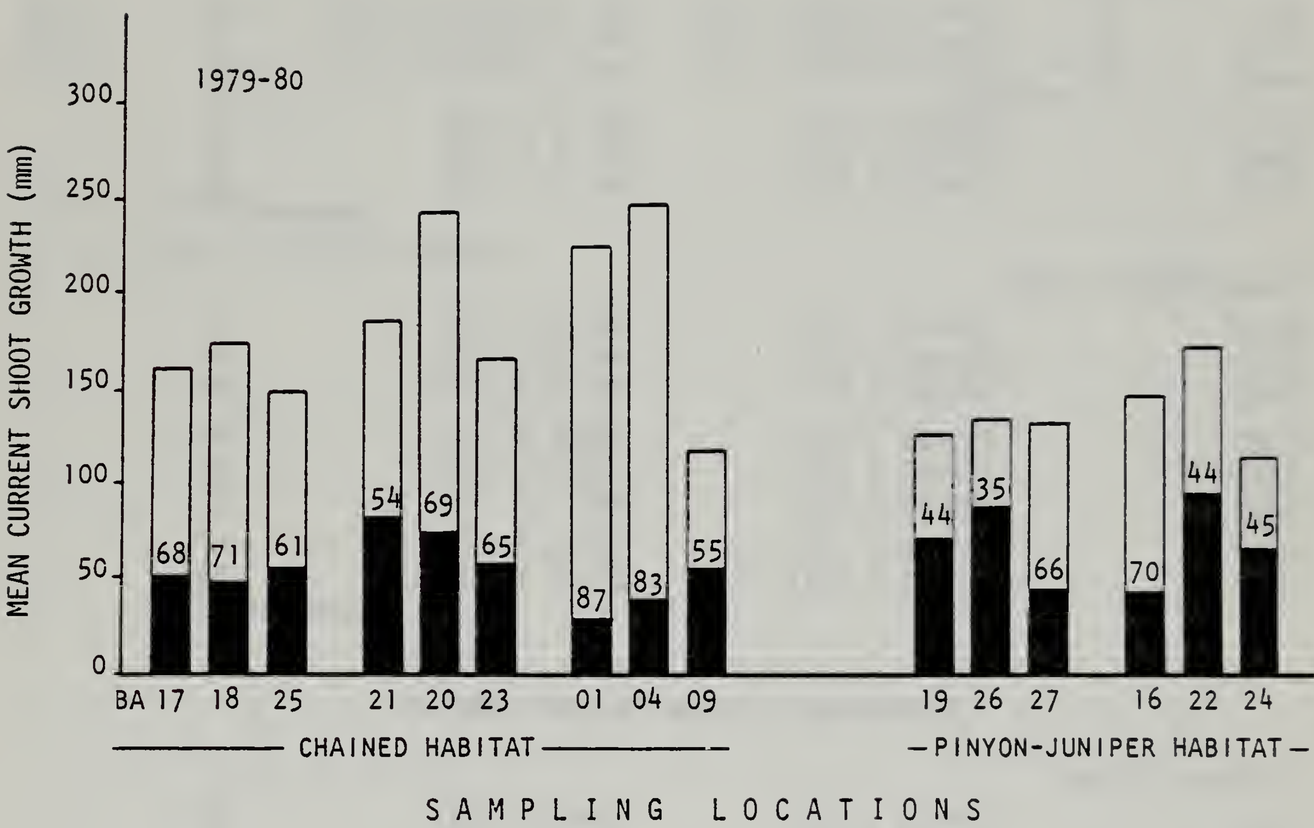


Fig. 8.2.2-1 (Cont). Trends in production and utilization of bitterbrush. Bars represent mean current shoot growth. Shaded areas represent the length of current shoot growth remaining after winter browsing. Numbers inside the bars represent the percent of current shoot growth consumed by deer. Transect numbers are indicated below bars.

Table 8.2.2-1. Browse Production and Utilization, 1979-80.

Transect	A PRODUCTION length of new shoots in fall (mm) Mean±SE (n)*	B Lengths of shoots remaining in spring (mm) Mean±SE (n)*	C UTILIZATION: in percent $C = \frac{A-B}{A} \times 100$
	Bitterbrush, chained rangeland habitat:		
Reference Area:			
BA17	162±16.7 (10)	52±10.3 (10)	68
BA18	173±11.8 (10)	51± 8.3 (10)	71
BA25	150±19.5 (10)	58±11.5 (10)	61
BA01	228±26.6 (10)	30± 3.1 (10)	87
BA04	249±25.8 (10)	42± 7.7 (10)	83
BA09	119±14.3 (10)	54± 7.1 (10)	55
			Combined 71
Developmental Area:			
BA30	189±16.1 (15)	39± 8.7 (14)	79
BA31	230±20.4 (15)	58± 8.7 (15)	75
BA32	202±20.0 (15)	32± 6.4 (15)	84
BA20	242±23.1 (10)	76±22.9 (10)	69
BA21	189±22.3 (10)	87±22.0 (10)	54
BA23	166±12.9 (10)	58±11.2 (10)	65
BA28	157±16.9 (10)	60±12.3 (10)	62
BA33	154±11.4 (15)	22± 4.1 (15)	86
			Combined 72
	Bitterbrush, pinyon-juniper habitat:		
Reference Area:			
BA19	126±15.2 (10)	70±12.0 (10)	44
BA26	133±12.7 (10)	86±14.1 (10)	35
BA27	131±16.7 (10)	45±10.2 (10)	66
			Combined 48
Developmental Area:			
BA16	145±10.2 (10)	43±11.5 (10)	70
BA22	170±22.2 (10)	96±19.1 (10)	44
BA24	107±12.2 (10)	59±11.9 (10)	45
			Combined 53

* n = number of shrubs sampled

Table 8.2.2-1. (Continued).

Transect	A PRODUCTION length of new shoots in fall (mm) Mean±SE (n)*	B Lengths of shoots remaining in spring (mm) Mean±SE (n)*	C UTILIZATION: in percent $C = \frac{A-B}{A} \times 100$
	Mt. mahogany, chained rangeland habitat:		
BA28	150±32.9 (10)	65±17.8 (10)	57
BA17	93± 8.1 (10)	39± 8.7 (10)	58
BA29	108±12.4 (10)	56±11.3 (10)	48
		Combined	54

* n = number of shrubs sampled

Table 8.2.2-2. Browse production, 1980.

Transect	PRODUCTION: length of new shoots in fall (mm) Mean ± SE (n)*
BITTERBRUSH, CHAINED RANGELAND HABITAT:	
BA17	126 ± 8.8 (10)
BA18	175 ± 17.8 (10)
BA25	149 ± 22.6 (10)
BA21	140 ± 16.6 (10)
Watered during summer 1980:	
BA20	211 ± 24.0 (10)
BA32	184 ± 13.7 (15)
Not watered; control transects:	
BA23	148 ± 17.3 (10)
BA30	146 ± 15.1 (15)
BA31	203 ± 10.3 (15)
On Big Jimmy ridge:	
BA01	137 ± 11.1 (10)
BA04	161 ± 15.9 (10)
BA06	121 ± 13.7 (10)
BA09	88 ± 12.2 (10)
BITTERBRUSH, PINYON-JUNIPER WOODLAND:	
BA19	119 ± 10.1 (10)
BA26	109 ± 10.9 (10)
BA27	107 ± 7.0 (10)
BA16	126 ± 15.9 (10)
BA22	137 ± 15.5 (10)
BA24	81 ± 9.9 (10)

* n = number of shrubs sampled

were compared with transects BA23, 30, and 31 (control). Among-transect samples were shown to be from the same population by analysis of variance; among-control samples were similarly analyzed. A nested ANOVA was performed, which gave significant F-tests for among-transect and among-shrub levels of the analysis. Among-transect results were: F=3.55; P<0.025; $F_{0.05(4,60)} = 2.53$. Among-shrub results were: F=2.35; P<0.001; $F_{0.05(60,585)} = 1.35$. In terms of variance components, 4 percent of the variance occurred among transects, 11 percent among shrubs, and 85 percent among shoots. A Scheffe's test was used to compare the two watered transects with the three control transects. The watered transects had significantly more shoot growth; mean differences in growth between watered shrubs and control shrubs was 31.8mm.

The interrelationships of browse production, utilization, and deer pellet group counts (Table 8.2.2-3) were analyzed by correlating pairs of browse and pellet count measurements (data pairs being obtained from the same quadrat). During the past two years a weak but significant correlation had been found for pellet counts and percent utilization in chained rangeland habitat. During this past year, however, no significant positive correlations were obtained. That pellet group counts do not correlate, or at least are only weakly correlated, with browse utilization suggests merely that feeding and defecation by deer does not necessarily occur in the same locations. Data obtained from browse and pellet count studies, therefore, should be considered separate indicator variables, both of which reflect overall deer abundance in the Tract C-b area.

The absence of significant correlations between production and percent utilization (except in one case, Table 8.2.2-3) indicates that the percentage of the current shoot growth consumed by deer is not a function of the amount of growth produced. The rather constant or uniform characteristic of percent utilization is shown in Table 8.2.2-3 in terms of coefficients of variation (CV). The low CVs associated with percent utilization quantifies what has been observed in past years. Namely, regardless of how much a shrub produces in terms of shoot length, deer tend to take a constant percent of it. Thus, percent utilization is a better indicator variable for evaluating utilization than length of shoots remaining, which tends to be quite variable by comparison. It should be mentioned in the context of the CVs shown that pellet counts were more variable than browse measurements. This is contrary to what is generally believed, and points out that the relative ease with which adequate sample sizes can be obtained for pellet counts relates to speed of sampling rather than to variability of data.

8.2.2.6 Conclusions

Both bitterbrush production and utilization were lower on the browse transects in 1980 than in 1979. Percent utilization is a better indicator for evaluating utilization than length of shoots remaining. Production and utilization of browse has not been significantly affected by developmental activities on Tract C-b.

Table 8.2.2-3. Interrelationships of browse production, utilization, and deer pellet group counts. Data obtained from chained rangeland habitat, 1979-80.

	CORRELATIONS (r)			COEFFICIENTS OF VARIATION ($CV=\frac{SD}{\bar{X}} \cdot 100$)			
Transect	Pellet Counts and Percent Utilization	Production and Percent Utilization	Production and Length of Shoots Remaining	Pellet Counts	Percent Utilization	Production	Lengths of Shoots Remaining
BA17	-0.69*	-0.40	0.87*	76.0	17.0	32.6	62.8
BA18	-0.21	-0.50	0.79*	91.0	16.7	21.7	51.3
BA25	0.24	0.11	0.47	46.9	44.2	41.1	62.5
BA21	0.02	-0.58	0.77*	59.4	40.0	37.3	80.1
BA20	0.34	-0.84*	0.94*	66.6	24.2	30.2	95.4
BA23	0.29	-0.23	0.52	85.6	27.1	24.6	60.8
BA01	0.47	0.62	0.35	51.9	7.0	36.9	33.1
BA04	-0.39	0.40	0.32	61.7	10.4	32.9	57.7
BA09	-0.42	0.37	0.40	89.2	49.0	38.1	42.0

* = significance at $\alpha = 0.05$; df = 8; $r_{0.05} = 0.63$.

8.2.3 Migrational Patterns and Phenology

8.2.3.1 Scope

Deer road counts have proven useful for showing deer distributions along the Piceance Creek highway. The structural road count observations are repeatable, and provide a means of quantifying changes in relative abundance and distribution.

8.2.3.2 Objectives

The main objectives of deer road count studies are to document the distributional patterns of deer along the Piceance Creek drainage during the Fall-through-Spring period, and to record the times of the seasonal migrational movements.

8.2.3.3 Experimental Design

Counts were made at approximately weekly intervals beginning in mid-September and ending in May. Observations were made along 41 miles of highway, from Highway 64 on the White River to Highway 13 at Rio Blanco. Counts were made from a vehicle driving approximately 30 m.p.h. All travel was changed for each consecutive count. Deer were recorded for one-mile intervals, and according to feeding locations on slopes or in meadows. Stations are shown on Exhibit C (found in the back cover jacket of this volume).

8.2.3.4 Method of Analysis

At the present time, data are evaluated by comparisons of histograms showing numbers of deer observed along the Piceance Creek road at selected periods throughout the winter.

8.2.3.5 Discussion and Results

The fall migration of deer into the Tract C-b area again occurred during the mid-October period. Also, the departure of deer from the agricultural meadows along Piceance Creek again occurred during early May. The phenology of deer migration, therefore, has remained basically the same over the past six years.

The pattern of deer occurrence along the Piceance Creek road has the potential of being an indicator of impacts due to Tract C-b development. For example, if deer are displaced to either side of Tract C-b during their fall migration from the higher elevations to the south of the Tract, conceivably this displacement could be manifested in relatively fewer deer occurring in the meadows immediately north of active development locations. However, this past year's observations for the October-November period (Figure 8.2.3-1) indicate no such shift in relative numbers of deer when compared to previous years.

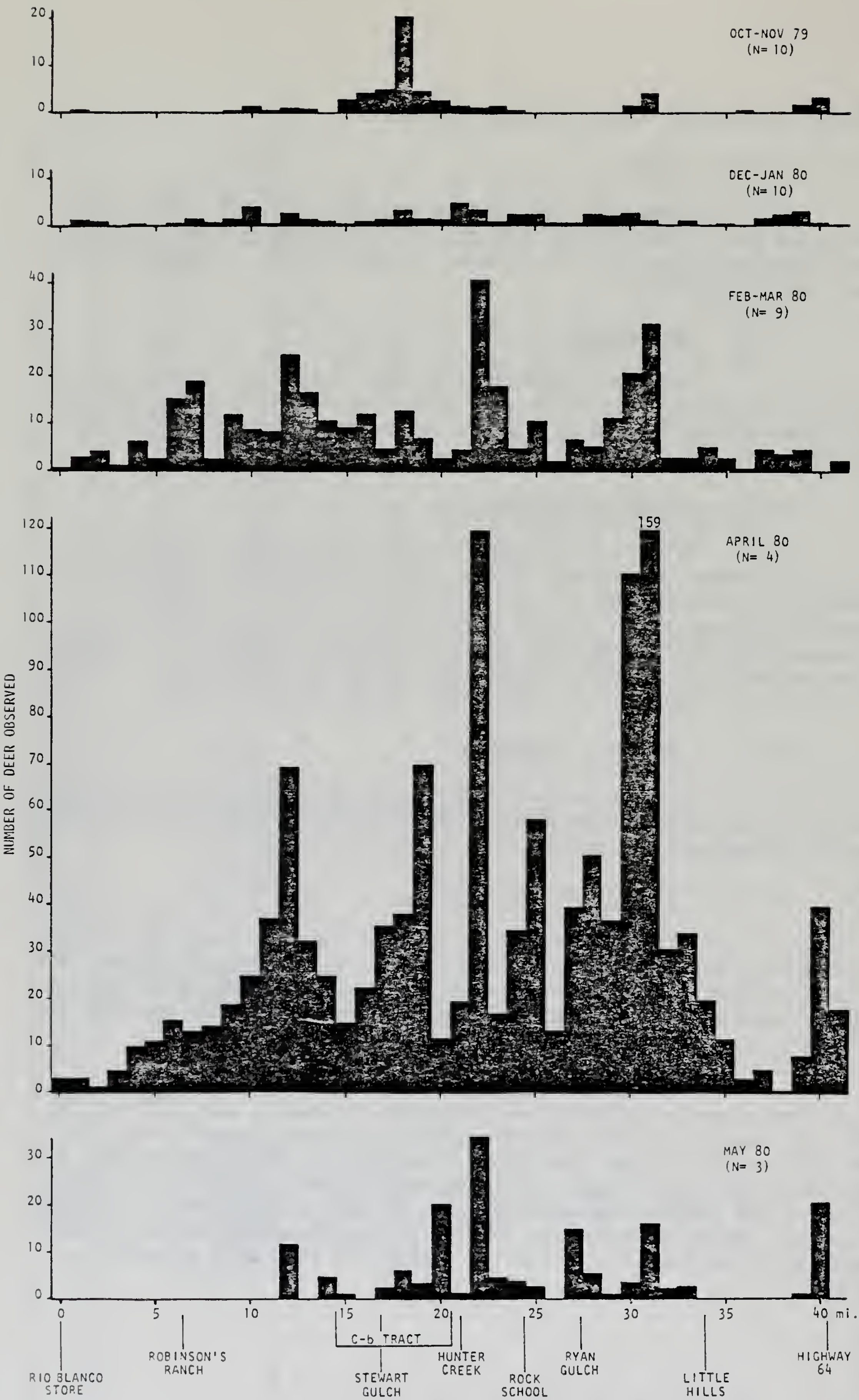


Fig. 8.2.3-1. Summary of deer road counts for 1979-80. Heights of bars are means; sample sizes (N) are the number of road counts for the period.

8.2.3.6 Conclusions

The migrational movements and distribution along the highway of the mule deer in the Piceance Basin have basically remained the same over the years. The high road count for the year was 1409 deer recorded in April.

8.2.4 Road Kill

8.2.4.1 Scope

Mule deer road kill data were collected weekly along Piceance Creek highway to obtain information on the number and location of deer killed by vehicles on the highway.

8.2.4.2 Objectives

The main objectives of collecting road kill data were to obtain accurate mule deer fatality estimates and to use this information in conjunction with other deer study data to identify problem areas so the necessary mitigative measures could be initiated.

8.2.4.3 Experimental Design

Weekly road kill data were collected from September 1978 through May 1979 at the same stations used for mule deer migrational patterns and phenology study. The dead deer were aged, sexed, and tagged. In addition, one ear was removed to avoid double counting. Road kill information was compared to Division of Wildlife information collected to ensure that all deer found were recorded.

8.2.4.4 Method of Analysis

Currently, time series tabulations and graphs are used for analysis. When several years of data have been collected, nonparametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) will be used.

8.2.4.5 Discussion and Results

Data for mule deer killed along the Piceance Creek Highway from 1977 through 1980 are shown in Figure 8.2.4-1. There was a 27% drop in the number of roadkills comparing 79-80 data to data from 78-79. This decrease can probably be attributed to the presence of fewer deer along the highway. The mule deer herd size was greatly reduced by the severe winter of 78-79.

Total deer roadkill for the Piceance Creek Highway is shown in Figure 8.2.4-2. Almost twice as many deer were killed along the lower 20 mile section as along the upper 20 mile section. This is not surprising since there is twice as much traffic toward the Rio Blanco Store terminus of the Piceance Creek Hignway as the White River terminus.

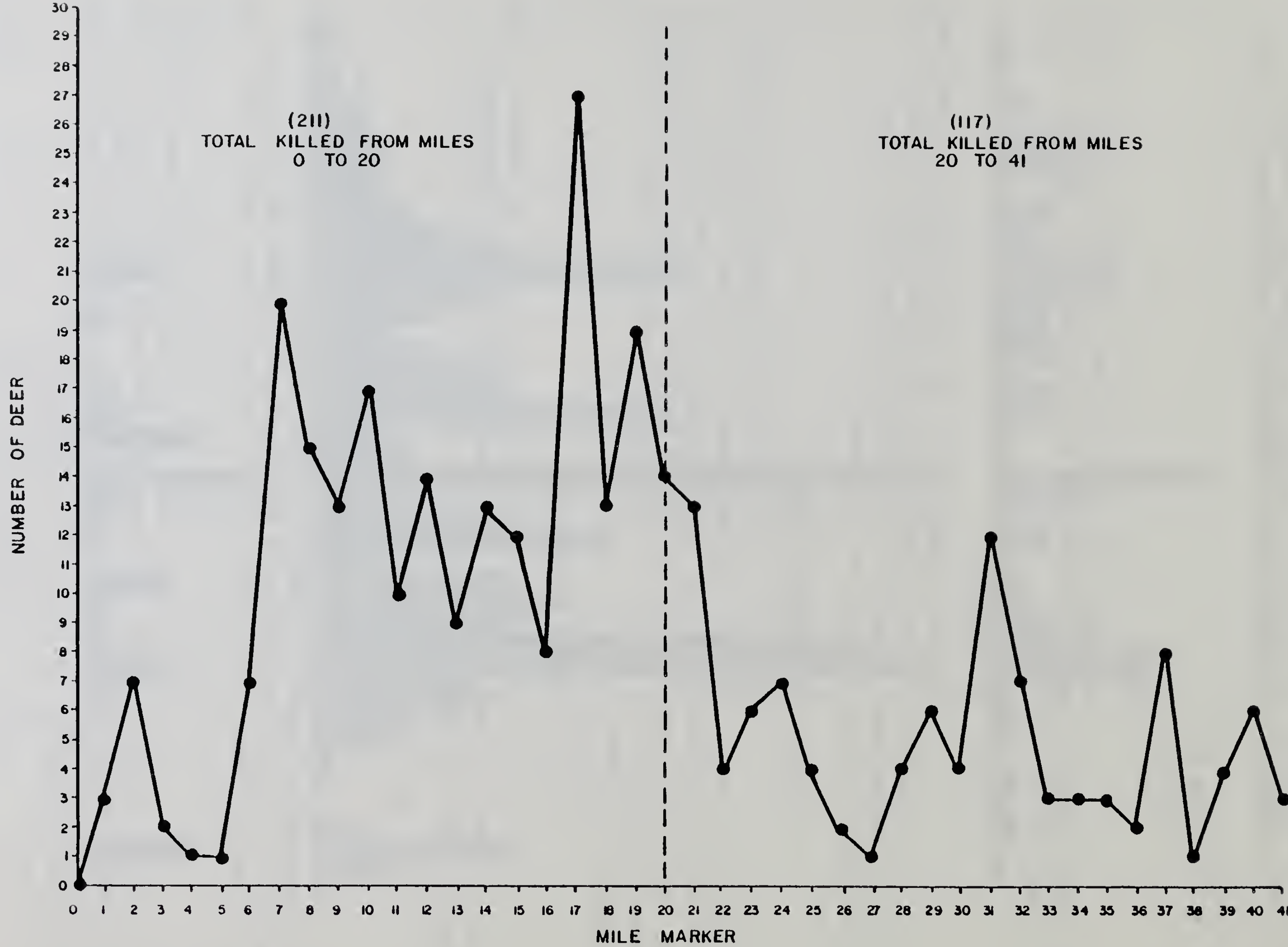


FIGURE 8.2.4-1
CUMLATIVE PICEANCE CREEK ROAD KILL
9/77 - 5/80

FIGURE 8.2.4-2

MULE DEER ROAD KILL, PICEANCE CREEK - COUNTY ROAD 5

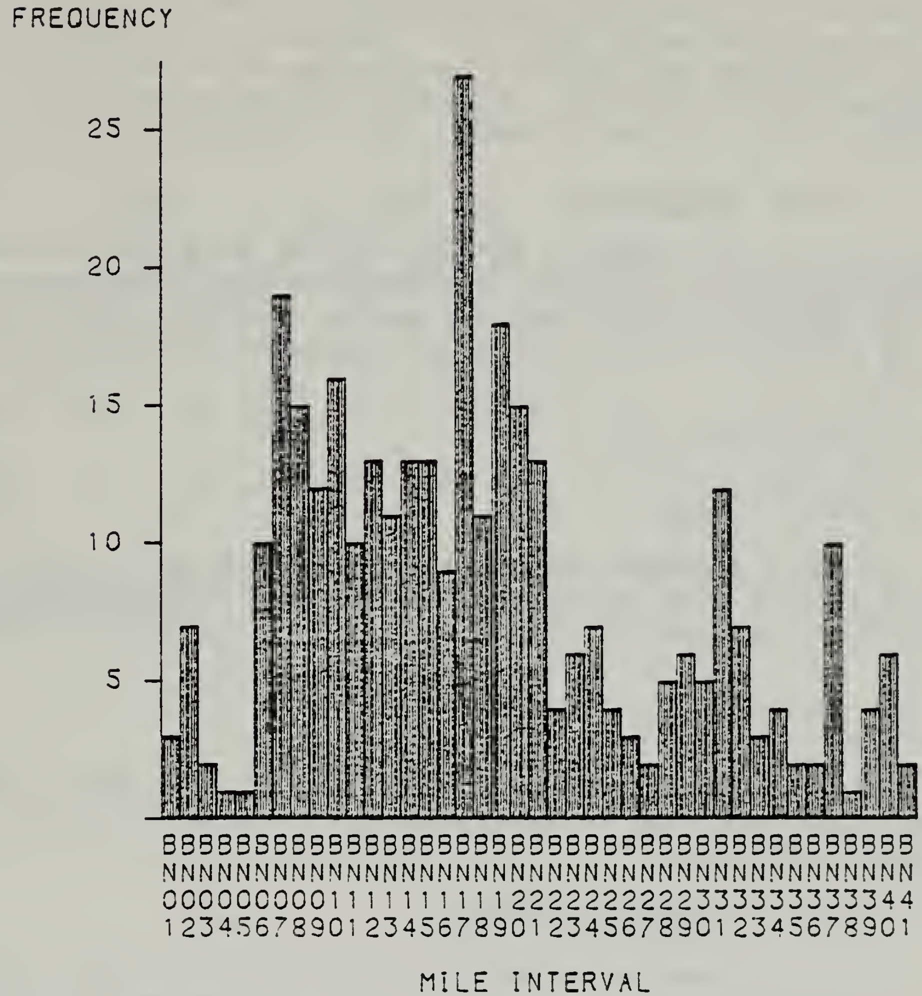


Table 8.2.4-1 gives the age and sex breakdown of the roadkills along the highway. The percentile of male fawns increased for 79-80 data in comparison with 78-79 data (22 percent and 10 percent, respectively). Comparing the same years for mature does shows a decrease of 20 percent (41 percent for 79-80 vs. 61 percent for 78-79). These trends are reversed when comparing data from 78-79 to 77-78; male fawn roadkills decreased while doe roadkills increased. This shifting in numbers will be monitored closely.

8.2.4.6 Conclusions

The number of mule deer killed along the Piceance Creek Highway has varied over the years. The number of deer killed seems dependent on herd size, vehicular traffic load and weather conditions. More information is needed to establish the degree these variables are interrelated. See also Section 12.3.2.

8.2.5 Natural Mortality

8.2.5.1 Scope

Baseline studies have shown winter kills to be largely restricted to the lateral draws and bottomland sagebrush. Checking these areas each spring has helped in observing changes in the relative magnitude of deer mortality.

8.2.5.2 Objectives

The objectives of this study are to estimate deer mortality on a yearly basis in order to document long-term trends and to aid interpretations of other deer data.

8.2.5.3 Experimental Design

Sampling was done in the spring on 10 plots located in lateral draws and sagebrush gulches (see Exhibit C). The age and sex of all deer that had died the previous winter were recorded, and each carcass marked with a metal tag stamped with the current year. The presence of either the skull of pelvic girdle was required to constitute a carcass.

8.2.5.4 Method of Analysis

Nonparametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) will be used when several additional years of data have been gathered. Only tabular presentations will be used until then.

8.2.5.5 Discussion and Results

Data from mortality studies can, of course, be correlated with other measurements of deer abundance. These evaluations, however, will become more meaningful after more years of data have been accumulated.

TABLE 8.2.4-1

Piceance Creek Road Kill

(Piceance Creek Road from 0 thru Mile 41)

Date	DOES		FAWNS				BUCKS		Unknown	Total
			Male		Female					
	#	%	#	%	#	%	#	%		
9/77-5/78	40	41	28	29	22	22	8	8	2	100*
9/78-5/79	80	61	13	10	27	21	11	8	0	131
9/79-5/80	40	41	22	22	26	27	3	3	5	96

*Total road kill was 125 deer. This figure was derived from combining DOW data with C-b data.

Presently it should be pointed out that the deer mortality was higher during the 1979-1980 winter period (Table 8.2.5-1) than during the previous and more severe winter of 1978-1979. The Department of Wildlife (DOW) also recorded a high winter mortality for the 1979-80 winter. This result is surprising and no explanation can be substantiated at this time. However, one possible explanation may be that the severe winter of 1978-1979 left the surviving does in such poor condition that they had fawns that were in only fair or poor condition. These does and fawns may have entered into the 1979-1980 winter in less than optimum condition, thereby being more susceptible to winter mortality.

8.2.5.6 <u>Conclusions</u>

Deer mortality was higher during the 1979-1980 winter than during the previous years (1977-1979).

8.2.6 Age-Class Composition

8.2.6.1 <u>Scope</u>

Estimating the age-class composition of the deer herd in the fall faciliates evaluating the magnitude of fawn mortality that occurred during spring and summer while deer were on summer range. Estimates taken in spring permit estimating the fawn mortality that occurred while deer were on winter range in the C-b area.

8.2.6.2 <u>Objectives</u>

The main objective of the age-class study is to estimate fawn-adult ratios in fall and in spring.

8.2.6.3 <u>Experimental Design</u>

Sampling locations were restricted to the meadows of major drainages within five miles of Tract C-b. Counts occurred in November and in April. Observations took place during times of high concentrations. The deer that could be clearly observed were recorded as adults, fawns or bucks. No attempt was made to recognize yearlings, and bucks (and the number of points on both antlers) were recorded only when feasible.

8.2.6.4 <u>Method of Analysis</u>

Data from this study will be used mainly to aid in the interpretation of the results of other deer studies.

8.2.6.5 <u>Discussion and Results</u>

Only 6.9 fawns per 100 adult deer were recorded during April 1980 (Table 8.2.6-1). During April 1979, 12 fawns per 100 adult deer were recorded. These findings support the surprising results mentioned above relating to deer mortality. Why fawn mortality was higher during the winter of

TABLE 8.2.5-1

Results of Deer Mortality Studies

Year	Sampling Location	No. of carcasses found	Hectares sampled (acres)	Carcasses per hectare (/acre)
1979-80	Sagebrush Internal draw	60	70.5(174)	0.851(0.345)
1978-79	Sagebrush-lateral draw	34	70.5(174)	0.482(0.195)
1977-78	Sagebrush-lateral draw	25	70.5(174)	0.355(0.144)
1976-77	Interim monitoring period - No sampling			
1975-76	Lateral draws	8	7.25(18)	1.10(0.44)
1974-75	Lateral draws	11	7.25(18)	1.52(0.61)

TABLE 8.2.6-1

Age Class Composition of Mule Deer Wintering Near Tract C-b.

Date	Fawns	Does	Bucks	Adults	Fawns/ 100 Does	Bucks/ 100 Does	Fawns/ 100 Adults
Nov. 15-23, 1977	85	107	28	135	79.4	26.2	63.0
Apr. 04-07, 1978	68			104			65.0
Nov. 13-27, 1978	151	159	35	194	95.0	22.0	77.8
Apr. 20-26, 1979	41			343			12.0
Nov. 27-Dec. 7, 1979	46	62	8	70	74.1	12.9	65.7
Apr. 21-24, 1980	26			375			6.9

1979-1980 than during the more severe winter of 1978-1979 is not known. See Section 8.2.5.5 for one possible explanation for the difference in fawn counts.

8.2.6.6 Conclusions

Fawn counts in 1980 were 6.9 fawns per 100 adult deer which was lower than the count in 1979.

8.3 Medium-Sized Mammals

Studies of medium-sized mammals are restricted to coyotes and lagomorphs (cottontails and jackrabbits). Monitoring of these animal groups provides trend information on the relative abundance of larger mammalian predators to prey species present within the Tract C-b ecosystem.

8.3.1 Coyote Abundance

8.3.1.1 Scope

Coyotes are of ecological significance because they are a major predator on Tract C-b. They are also of general interest to the public with both strongly negative and positive supporters.

8.3.1.2 Objectives

The objective of the coyote study is to obtain trend information on the relative abundance of coyotes on and near Tract C-b.

8.3.1.3 Experimental Design

Two coyote scent-station surveys are being used following the design of the U.S. Fish and Wildlife Service (Linhart and Knowlton 1975). Sampling was done in early October along 30 miles of road segments on and near the Tract. The presence of tracks was checked once the day after scent stations were set out. This survey technique is also being used to record information on wildlife species other than coyotes.

8.3.1.4 Method of Analysis

Relative abundance is calculated as a visit frequency. The long-term trend data being gathered on Tract will be evaluated in the context of the state-wide data gathered by the U.S. Fish and Wildlife Service.

8.3.1.5 Discussion and Results

The relative index value of 50 for coyote abundance (Table 8.3.1-1) was calculated as an average for two 50-station transects. This value, when compared to the indices of previous years, is considerably below the overall average value of 112. Ranchers in the area indicated that they hunted coyotes during the winter. However, no professional trappers were hired as had been the case in 1978. No trends are apparent when the indices of abundance

TABLE 8.3.1-1

Results of the Coyote Scent Station Survey, 1980

Line	Location	No. of Stations	No. of Visits
1	Big Jimmy	25	2
2	Scandard Ridge	10	0
3	Scandard Gulch	10	1
4	SG-15	10	0
5	SG-3	10	0
6	Stewart Ridge	15	1
7	West Stewart Valley	10	1
8	Bailey Ridge	10	0

$$\text{Index of abundance} = \frac{\text{No. of visits}}{\text{No. of stations}} \times 1000$$

$$= \frac{5}{100} \times 1000 = 50$$

Indices of Coyote Abundance

Year	C.B. Tract	USFWS (Colorado Average)
1979	70	91.5
1978	50	104.4
1977	130	104.4
1976	Interim	110.2
1975	122	74.4
1974	188	98.1

from C-b Tract are compared from those of the USFWS. Trends of coyote abundance will become more meaningful when additional years of data have been collected.

No new species of mammals were identified while conducting the coyote scent station surveys.

8.3.1.6 Conclusions

Coyote abundance for 1980 was calculated as a relative index value of 50. This value is below the average value of 112. No trends in coyote abundance are apparent at this time.

8.3.2 Lagomorphs

8.3.2.1 Scope

Cottontails and jackrabbits provide a potentially important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b. At some time in the future, however, its status could change. The lagomorph relative-abundance estimates are based on data collected along the BA-designated transects. (See Exhibit C for transect locations and Volume 2 Appendix for identification of transects.)

8.3.2.2 Objectives

The objectives of lagomorph studies are to obtain relative-abundance estimates for cottontails and jackrabbits on and near Tract C-b.

8.3.2.3 Experimental Design

Relative abundance indices of cottontails and jackrabbits were estimated along the twenty-seven transects used for deer pellet group and browse production-utilization studies. Counts of presence-absence data were made inside the deer quadrats, but were restricted to an area of 0.001 acre.

8.3.2.4 Method of Analysis

Yearly differences and habitat affinity evaluations can be analyzed using t-tests. Trend analyses and correlations can be readily applied as well, but these analyses will be more appropriate after 4 or 5 more years of data are gathered.

8.3.2.5 Discussion and Results

Comparisons of results for the past two years (Table 8.3.2-1) indicate no significant changes in lagomorph abundance levels. (Paired-t, df=14, P>0.05; and t=0.439, df=11, P>0.50). Also, no significant differences were found in relative abundance values between chained and pinyon-juniper habitat (t=0.387, df=25, P>0.50).

Table 8.3.2-1. Relative abundance of cottontails and jackrabbits, 1979-80. Each transect consists of twenty 0.001 acre plots.

Transects	No. of plots with lagomorph droppings
Chained rangeland habitat:	
BA01	15
BA02	12
BA03	16
BA04	6
BA05	13
BA06	12
BA07	12
BA08	11
BA09	10
BA17	14
BA18	19
BA25	12
BA20	8
BA21	8
BA23	12
Pinyon-juniper habitat:	
BA10	12
BA11	15
BA12	14
BA13	8
BA14	6
BA15	2
BA16	19
BA19	13
BA22	10
BA24	10
BA26	14
BA27	14

8.3.2.6 Conclusions

Developmental activities on Tract C-b do not seem to be affecting lagomorph abundance. No significant differences were detected when values of lagomorph relative abundance were compared from the chained rangeland versus pinyon-juniper woodland habitat.

8.4 Small Mammals

8.4.1 Species Diversity and Abundance

8.4.1.1 Scope

Small mammals are important as prey species. Monitoring changes in selected population abundance parameters will aid in assessing potential effects of pollutants before populations of larger animals are greatly affected.

8.4.1.2 Objectives

The objectives of small mammal monitoring on Tract C-b are to determine small mammal species composition, reproductive conditions, age class and relative abundances, and to see how the development of Tract C-b is affecting populations as manifested by these parameters. During 1980, field sampling was also performed to test whether watering of chained rangeland habitat affects small mammal abundance and diversity.

8.4.1.3 Experimental Design

Small mammal trapping was conducted in two habitat types: chained rangeland, and pinyon-juniper woodland. In chained rangeland habitat, trapping occurred at control and at development sites. Development sites were defined as locations where the water sprinkling system was in operation. See Figure 8.7.2-1. Trapping locations in the development area were chosen by randomly selecting seven sprinkler sites (five with low water treatment, and two with high water treatment). Control locations occurred in the same habitat, but at three distant locations surrounding the sprinkling system. At each of the control and development sites, parallel transects were established, each consisting of 10 live traps spaced at 5 meter intervals. Animals were removed from traps during mornings, and at this time all transects were moved approximately 15 meters. Moving traps each day was done to minimize recaptures and to sample a larger area of the habitat. Bait consisted of rolled oats. Trapping occurred for four days during July and during August. Trapping also occurred in pinyon-juniper habitat following the same design. Trapping in pinyon-juniper habitat was conducted as part of the original long-term monitoring program, and to provide additional control study sites.

8.4.1.4 Method of Analysis

Statistical analysis consisted of the one-way analysis of variance (ANVOA) and the Student-Newman-Keuls (SNK) multiple range test.

8.4.1.5 Discussion and Results

The main objective of small mammal studies during 1980 was to determine if the sprinkling program being conducted on Tract C-b in chained rangeland and habitat affects small mammal populations. The sprinkler system became operative on 27 May, five weeks prior to the July trapping period. The results obtained for July and August (Table 8.4.1-1) were obtained during a watering program consisting of intermittent sprinkling.

Three species of small mammals were commonly captured during July and August in chained rangeland habitat: the deer mouse, least chipmunk, and golden-mantled ground squirrel. Only one Apache pocket mouse was captured, and although Uinta chipmunks were commonly captured in pinyon-juniper habitat, none were taken at control or development sites in chained areas.

Differences in relative abundance of small mammals between control and development sites were evaluated using one-way ANOVA's and SNK tests. Results obtained for the three common species are shown in detail, along with a summary of the findings, in Table 8.4.1-2. The apparent avoidance of the watered areas by deer mice, and the apparent attraction to these areas by golden-mantled ground squirrels, is strongly indicated by the statistically significant difference between development and control sites that were obtained. It is likely that least chipmunks tended to avoid watered areas as well, although results are not as convincing.

Differences in capture frequencies between control and watered areas is probably due to rather immediate behavioral responses. Possibly, however, a response by plants occurred first, which altered food conditions. Yet, this seems unlikely after sprinkling began. But regardless of the casual factors involved, the results indicate that marked changes in small mammal populations can be expected to occur in areas receiving considerable amounts of water. Since the three species commonly captured represent part of the prey base for larger predatory mammals and birds, population changes of the magnitude detected during 1980 are of potential importance to the ecosystem.

Results of trapping in pinyon-juniper habitat, when compared to control areas in chained habitat, indicated no statistically significant differences in abundance levels between habitats for either deer mice or golden-mantled ground squirrels. The Uinta chipmunk, however, showed a distinct affinity for pinyon-juniper habitat, whereas the least chipmunk showed a strong affinity for chained habitat (tests for the above comparisons used ANOVA's with df=1).

8.4.1.6 Conclusions

Preliminary data show that deer mice tend to avoid watered areas, whereas, golden-mantled ground squirrels are attracted to these areas.

Trapping results in the pinyon-juniper habitat compared to the chained areas show similar patterns to past year's results. The least

Table 8.4.1-1. Relative abundance of small mammals, 1980[1]. Data compare watered areas in the chained rangeland habitat with control areas in chained and pinyon-juniper habitat. Actual number of animals captured is shown in brackets.

	Chained Rangeland Habitat						Pinyon-Juniper Habitat	
	Least Water		Most Water		Control		Control	
	JUL (300)[2]	AUG (300)	JUL (300)	AUG (120)	JUL (600)	AUG (600)	JUL (150)	AUG (150)
Deer Mouse *Peromyscus maniculatus*	20.3 {61}	15.3 {46}	16.3 {49}	11.7 {14}	26.8 {161}	27.8 {167}	34.7 {52}	23.3 {35}
Least Chipmunk *Eutamias minimus*	7.3 {22}	28.7 {86}	6.7 {20}	24.2 {29}	13.5 {81}	19.7 {118}	0.7 {1}	1.3 {2}
Uinta Chipmunk *Eutamias umbrinus*	0	0	0	0	0	0	5.3 {8}	11.3 {17}
Golden-mantled ground squirrel *Spermophilus lateralis*	10.7 {32}	4.0 {12}	10.7 {32}	8.3 {10}	4.7 {28}	0.7 {4}	4.0 {6}	0
Apache Pocket Mouse *Perognathus apache*	0	0	0	0	0.2 {1}	0	0	0

[1] Relative abundance = number of captures / 100 traps.

[2] Number of trap-nights (a trap-night is one trap set one night).

Table 8.4.1-2. Analysis of variance results concerning small mammal responses to the watering of chained rangeland habitat. See footnotes for definitions of abbreviations used.

TEST NO. 1. Deer Mouse Results, July 1980.
H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	12.038	4.68	8.9%
Error	117	2.572		91.1%

$F_{0.05(2,117)} = 3.09$ $P<0.025$ $(\bar{X}_1=2.7;\ \bar{X}_2=2.0;\ \bar{X}_3=1.6)$
Nonsignificant means (underlined): $\underline{\bar{X}_1\ \bar{X}_2}$ $\bar{X}_3$

Conclusion: reject H_o. Number of captures were not the same in the three locations, but differences were not sufficiently great to permit an unambiguous separation of means.

TEST NO. 2. Deer Mouse Results, August 1980.
H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	23.249	11.32	26.8%
Error	99	2.054		73.2%

$F_{0.05(2,99)} = 3.10$ $P<<0.001$ $(\bar{X}_1=2.8;\ \bar{X}_2=1.5;\ \bar{X}_3=1.2)$
Nonsignificant means (underlined): $\bar{X}_1$ $\underline{\bar{X}_2\ \bar{X}_3}$

Conclusion: reject H_o. Number of captures were significantly greater in the control locations.

Table 8.4.1-2. Continued.

TEST NO. 3. Least Chipmunk Results, July 1980.

H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	6.371	4.83	9.3%
Error	117	1.318		90.7%

$F_{0.05(2,117)} = 3.09$ $P<0.01$ $(\bar{X}_1=1.4;\ \bar{X}_2=0.7;\ \bar{X}_3=0.7)$

Nonsignificant means (underlined): $\bar{X}_1$ $\underline{\bar{X}_2\ \bar{X}_3}$

Conclusion: reject H_o. Number of captures were significantly greater in the control location.

TEST NO. 4. Least Chipmunk Results, August 1980.

H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	8.219	3.10	6.9%
Error	99	2.650		93.1%

$F_{0.05(2,99)} = 3.10$ $P=0.05$ $(\bar{X}_1=2.9;\ \bar{X}_2=2.0;\ \bar{X}_3=2.4)$

Conclusion: accept H_o. Number of captures were not significantly different among locations.

Table 8.4.1-2. Continued.

TEST NO. 5. Golden-mantled Ground Squirrel Results, July 1980.
H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	5.400	6.67	13.1%
Error	117	0.809		86.7%

$F_{0.05(2,117)} = 3.09$ $P<0.005$ ($\bar{X}_1$=0.5; $\bar{X}_2$=1.1; $\bar{X}_3$=1.1)

Nonsignificant means (underlined): $\bar{X}_1\ \underline{\bar{X}_2\ \bar{X}_3}$

Conclusion: reject H_o. Number of captures were significantly less in the control location.

TEST NO. 6. Golden-mantled Ground Squirrel Results, August 1980.
H_o: $\mu_1 = \mu_2 = \mu_3$

Source of Variation	DF	MS	F	Variance Components
Among locations	2	3.386	22.96	43.8%
Error	99	0.147		56.2%

$F_{0.05(2,99)} = 3.10$ $P<<0.001$ ($\bar{X}_1$=0.1; $\bar{X}_2$=0.4; $\bar{X}_3$=0.8)

Nonsignificant means (underlined): $\bar{X}_1\ \bar{X}_2\ \bar{X}_3$

Conslusion: reject H_o. All means are significantly different. Number of captures were significantly less in the control location than in the two water treatment locations.

Table 8.4.1-2. Continued.

SUMMARY OF RESULTS. Asterisks indicate significant habitat affinities.

Species	Date	High Water	Low Water	Control
Deer mouse	July			*
	August			*
Least chipmunk	July			*
	August			
Golden-mantled ground squirrel	July	* (differences not significant between the two water treatments)		
	August	*		

$\overline{X}_1$ = mean number captures, control location.

$\overline{X}_2$ = mean number captures, low water treatment location.

$\overline{X}_3$ = mean number captures, high water treatment location.

μ_1 = true population mean, control location.

μ_2 = true population mean, low water treatment location.

μ_3 = true population mean, high water treatment location.

SNK = Student-Newman-Keuls multiple range test.

chipmunk still shows a strong preference for the chained habitat, whereas, the Uinta chipmunk prefers pinyon-juniper woodlands.

8.5 Avifauna

A wide variety of birds exist on Tract C-b and in the surrounding area. Avifauna were monitored to determine potential effects of habitat disturbance on species abundance.

8.5.1 Songbird Relative Abundance and Species Composition

8.5.1.1 Scope

Songbirds were monitored during their breeding season to determine effects of development on avifauna. It is anticiapted that habitat disturbance and increased human activity may effect population densities and relative abundance of the more prominent species. Certain species may be more affected by man-made impacts than others.

8.5.1.2 Objectives

Objectives of the program are to evaluate effects of development activity on songbird densities, species abundance and diversity by comparing control to developmental transect observations.

8.5.1.3 Experimental Design

Monitoring the avifauna transects occurs in May during the peak of the breeding season. Monitoring efforts are consistent with past sampling deisgns in that two transects in pinyon-juniper woodland and two transects in chained pinyon-juniper rangeland are sampled. In addition, in 1980 a new avifauna transect was established in the sprinkler-irrigation area (See Figure 8.7.2-1). One transect in each habitat type (Transects 1(BH01) and 4(BH04)) is located in an area which will not be disturbed by oil shale development. The remaining three transects (Transects 2(BH02), 3(BH03), and 5(BH05)) are located within each habitat where some disturbance from oil shale development is anticipated. All transects are 800 meters long and are permanently marked with steel rebar stakes and flagging. The method employed for censusing is the strip transect method as described by Emlen (1977) with slight modifications. This method provides data from which quantitive estimates of density of songbird-like species can be calculated.

8.5.1.4 Method of Analysis

The population density estimates for species observed on strip transects were determined by one of three methods described by Emlen (1971) which depended on the conspicuousness of the species to the observer. Since the validity of any of these methods varied for different species, professional judgment, based on experience with the conspicuousness of various species within different habitats during different seasons, was used in selecting the best density estimator. The Shannon-Weiner calculations (Pielou 1966) were used to compute indices of species diversity (H'), maximum diversity

H'_{max})and equitability (J) for each habitat sampled by strip transect procedures. Symbols are defined in Table 8.5.1-1. The Hutchenson's t-test was used to test the null hypothesis that two sampled populations have the same diversity. The least squares linear regression model was used to determine if a linear trend exists for a set of observations.

Additional analysis included: analyzing visual trends for species on transects and plotting species number by years and by transects.

8.5.1.5 Discussion and Results

A list of bird species observed on Tract C-b during the 1980 census period is given in Table A8.5.1-1. Included in the table are species that were observed, but not included in the quantitative analysis because they were not observed within the strip corridor or because specific habits of species, such as Swainson's hawk and common raven, rendered them unsuitable for this type of quantitative analysis.

Relative abundance and species density for 1980 are similar to previous year's data (1977-1979). Tables A8.5.1-2 through A8.5.1-6 summarize strip transect results and estimates of relative abundance and density for each transect. Brewer's sparrow, green-tailed towhee and vesper sparrow (listed in decending order) were the most abundant species in the chained pinyon-juniper rangeland while the Clark's nutcracker, mountain chickadee, black-throated gray warbler, solitary vireo, and chipping sparrow were the most abundant species in the pinyon-juniper woodland.

The Shannon-Weiner diversity indices for the avifauna transects for 1977 through 1980 are presented in Table 8.5.1-1. The diversity indices have remained fairly consistent over the years. The greatest H, H max and E(H) occur on transect 4 while least of these occur on transect 1. The greatest J (equitability) takes place on transect 2 whereas the least occurs on transect 1. The only consistent estimate from year 1977 to 1980 for all transects is J for transect 4, showing a slight increase.

Results from the Hutchenson's t-test are shown in Table 8.5.1-2. The null hypothesis that there was no difference in population diversity of species between control and developmental transects was tested. The null hypothesis was accepted for all tests showing that species diversity is similar between compared transects.

Trend analysis conducted on avifauna data show no statistical trends for species or groups on any transects over the years (1977-1980). See Table 8.5.1-3. In addition to the avifauna studies, birds were casually monitored through the year; several sightings were noteworthy. One, a belted kingfisher, was seen several times along Piceance Creek by the C-b Tract access road. In October there were large concentrations of common nighthawks on C-b tract, also several species of waterfowl have been observed using the treatment ponds, including: Canada goose, horned grebe and mallards.

TABLE 8.5.1-1

AUIFAUNA INDICES OF DIVERSITY

1977-1980

Transect	Vegetation Type	Year	$\hat{H}$	$\hat{H}$-Max	$\hat{J}$	E $(\hat{H})$	Var $(\hat{H})$
1	Chained Pinyon-Juniper Rangeland (Control)	1977	1.494	2.079	0.718	1.454	0.009
		1978	1.665	2.398	0.694	1.634	0.007
		1979	1.166	1.792	0.651	1.152	0.003
		1980	2.025	2.489	0.815	1.908	0.017
2	Pinyon-Juniper Woodland (Developmental)	1977	2.469	2.890	0.854	2.432	0.003
		1978	2.398	2.708	0.886	2.350	0.004
		1979	2.272	2.485	0.914	2.236	0.002
		1980	2.425	2.639	0.919	2.277	0.009
3	Chained-Juniper Rangeland (Developmental)	1977	1.950	2.197	0.888	1.895	0.004
		1978	1.885	2.398	0.786	1.868	0.003
		1979	1.526	1.946	0.784	1.508	0.003
		1980	2.271	2.708	0.839	2.143	0.015
4	Pinyon-Juniper Woodland (Control)	1977	2.740	2.944	0.931	2.709	0.001
		1978	2.545	2.890	0.881	2.522	0.002
		1979	2.189	2.398	0.913	2.168	0.002
		1980	2.463	2.944	0.837	2.329	0.014
5	Chained Pinyon-Juniper Rangeland (Irrigation Sprinkler System) (Control)	1980	2.197	2.639	0.832	2.034	0.020

Notes:

(1) $\hat{H}$ is an estimate of $\hat{H}$ which is a measure of diversity developed by Shannon.

(2) $\hat{H}$ max is an estimate of $\hat{H}$ max which is a measure of the maximum possible diversity for a set of data consisting of k categories.

(3) $\hat{J}$ is an estimate of $\hat{J}$ which is termed evenness, homogeneity or relative diversity

(4) E $(\hat{H})$ is the expectation of $\hat{H}$.

(5) VAR $(\hat{H})$ is the variance of $\hat{H}$.

(6) $\hat{H}$ is the population diversity, $\hat{H}$ Max is the population maximum diversity and $\hat{J}$ is the population evenness.

TABLE 8.5.1-2

HUTCHESON'S t-TEST FOR TESTING FOR EQUAL POPULATION DIVERSITIES OF TRANSECTS

Transects To be Tested	Set of Hypotheses To be Tested	Variances of Diversities Associated With each Transect	Standard Deviation of Sum of Both Transects	Diversity Estimate for Each Transect	Calculation of Test Statistic t	Number of Observations in Each Transect	Degrees of Freedom	Critical Value t_{cr}	Accept Null Hypothesis ?
Transect 1 and Transect 3	Ho: $H_1 = H_3$ Ha: $H_1 \neq H_3$	$S^2_{H_1} = 0.01727$ $S^2_{H_3} = 0.01468$	$\hat{S}_{H_1-H_3} = 0.1787$	$\hat{H}_1 = 1.9079$ $\hat{H}_3 = 2.1433$	$t = 1.3173$	$n_1 = 47$ $n_3 = 55$	$df_{1,3} = 100$	$t = 1.290$	No
Transect 1 and Transect 5	Ho: $H_1 = H_5$ Ha: $H_1 \neq H_5$	$S^2_{H_1} = 0.01727$ $S^2_{H_5} = 0.01979$	$\hat{S}_{H_1-H_5} = 0.1925$	$\hat{H}_1 = 1.9079$ $\hat{H}_5 = 2.0342$	$t = 0.6561$	$n_1 = 47$ $n_5 = 40$	$df_{1,5} = 200$	$t = 1.286$	Yes
Transect 2 and Transect 4	Ho: $H_2 = H_4$ Ha: $H_2 \neq H_4$	$S^2_{H_2} = 0.00871$ $S^2_{H_4} = 0.01418$	$\hat{S}_{H_2-H_4} = 0.1513$	$\hat{H}_2 = 2.2773$ $\hat{H}_4 = 2.3288$	$t = 0.3404$	$n_2 = 44$ $n_4 = 67$	$df_{2,4} = 100$	$t = 1.290$	Yes

Notes:

1. Selected $\alpha = .20$ as defined for Songbird relative abundance and specie composition, Section 8.5.1 in DMP dated February 23, 1979
2. $t_{cr} = t_{\alpha/2,\ df}$
3. If $t \leq |t_c|$ Accept Ho, otherwise reject Ho.
4. All subscripts correspond to transect numbers.

TABLE 8.5.1-3

Total Density Values for Avifauna Transects at C-b
During Spring Sample Period, 1977 - 1980

Transect	Vegetation Type	Year	Total Density/Ha
1 (BH01)	Chained Pinyon-Juniper Rangeland (Control)	1977	2.82
		1978	3.11
		1979	3.19
		1980	2.94
2 (BH02)	Pinyon-Juniper Woodland (Developmental)	1977	5.34
		1978	2.51
		1979	2.63
		1980	2.75
3 (BH03)	Chained-Juniper Rangeland (Developmental)	1977	3.51
		1978	4.90
		1979	3.00
		1980	3.44
4 (BH04)	Pinyon-Juniper Woodland (Control)	1977	7.4
		1978	4.82
		1979	3.70
		1980	4.19
5 (BH05)	Pinyon-Juniper Rangeland (Developmental-Sprinkler)	1980	2.51

8.5.1.6 Conclusions

Based on data collected thus far on Tract C-b, developmental activities have not caused any significant changes in songbird diversity or density in the study area.

8.5.2 Upland Gamebirds - Mourning Dove Relative Abundance

8.5.2.1 Scope

The mourning dove is the only upland gamebird present in sufficient numbers to be monitored. Field observations during the baseline data accumulation program indicated that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable monitoring program for them can be designed to determine changes over time; thus, a monitoring program for them is not warranted.

8.5.2.2 Objectives

The objective was to monitor the mourning dove populations to see if development of Tract C-b has affected their relative abundance.

8.5.2.3 Experimental Design

Methods used were identical to those used for songbirds. Throughout the year gamebirds observed were recorded on Wildlife Observation Reports.

8.5.2.4 Method of Analysis

The data were analyzed in the identical manner described for analyzing the relative abundance for the songbird-like population parameter.

8.5.2.5 Discussion and Results

Mourning dove data from 1977-1980 avifauna transects are shown in Table 8.5.2-1. The mourning dove population on Tract C-b, as elsewhere in the Piceance Basin, continues to show fluctuations in population size and distribution without any definable patterns. A trend that may be starting to show is that mourning doves seem to prefer transects located on the western side of the Tract versus the eastern side. The mourning dove population will continue to be monitored closely, especially to see if this possible trend becomes significant.

In addition to sightings on the transects, mourning doves were observed throughout the Tract in 1980 and a nest located on deer transect BA24 has been used by mourning doves for the past two years. No other gamebirds were observed on Tract C-b during 1980.

TABLE 8.5.2-1

Mourning Dove Estimates at Tract C-b for Spring Sampling Periods, 1977-80

Transect	Date	Observations	Coefficient Detectability	Density /Ha	% Relative Abundance
Chained Pinyon-Juniper (BH01)	1977	2	1.0	.03	2.5
	1978	1	1.0	.02	0.9
	1979	1	1.0	.04	1.2
	1980	3	1.0	.188	6.4
Pinyon-Juniper (BH02)	1977	4	1.0	.07	1.7
	1978	0	-	-	-
	1979	3	.74	.14	5.2
	1980	3	.74	.188	6.84
Chained Pinyon-Juniper (BH03)	1977	2	1.0	.03	2.1
	1978	0	-	-	-
	1979	0	-	-	-
	1980	0	-	-	-
Pinyon-Juniper (BH04)	1977	17	1.0	.29	5.9
	1978	5	.74	.17	4.2
	1979	0	-	-	-
	1980	0	-	-	-
Sprinkler Area (BH05)	1980	0	-	-	-

8.5.2.6 Conclusions

The mourning dove population is fluctuating from year to year with no definite pattern. Developmental activities on Tract C-b do not seem to be affecting the mourning dove population in the study area.

8.5.3 Raptor Activity

8.5.3.1 Scope

Raptor activity was monitored on Tract C-b on a continuing basis becuase of the importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

8.5.3.2 Objectives

The main objective of raptor monitoring was to detect changes in raptor utilization on or near Tract C-b.

8.5.3.3 Experimental Design

Trends in utilization of tract C-b and immediately contiguous habitats by raptors were established for the breeding season by determining the percent of known nest sites which were occupied by nesting pairs and comparing these data with data obtained during the baseline period and following years. Nest occupancy checks were made annually during April (great-horned owls, ravens, red-tailed hawks) and June (red-tailed hawks, eagles, great-horned owls). Throughout the year, any raptor sightings by the field biologists within the study boundary were recorded.

8.5.3.4 Methods of Analysis

Data analysis of nest occupancy was by professional judgement.

8.5.3.5 Discussion and Result

Raptor nesting records for 1976 through 1980 are listed in Table 8.5.3-1. Only three raptor nests had signs of activity during the April 1980 census. All these nests were occupied by red-tailed hawks. A total of eight nests (including the three active nests in April) were found to be active during the June census period. Active nesting raptors included: one pair of golden eagles, a pair of ravens, and six pairs of red-tailed hawks.

In addition to the nesting raptors, other raptors observed during 1980 in the study area included: great-horned owl, American kestrel, common nighthawk, march hawk, Cooper's hawk, Swainson's hawk, turkey vulture, and bald eagle.

The raptor population seems to be fairly stable in the study area with seemingly no effect from the developmental activities on Tract

TABLE 8.5.3-1

Raptor Nesting Record

Nest No.	Species	Status 1976 April	Status 1976 June	Status 1977 April	Status 1977 June	Status 1978 April	Status 1978 June	Status 1979 April	Status 1979 June	Status 1980 April	Status 1980 June
1	Unknown	I		I	I	I	I	I	I	I	I
2	Unknown	I		I	I	I	I	I	I	I	I
3	Unknown	I		I	I	I	I	I	I	I	I
4	Red-tailed Hawk	E or Y		I	I	I	I	I	I	I	I
5	Unknown	I		I	I	I	I	I	I	I	I
5a	Common Raven	-		-	E or Y	I	I	I	I	I	I
6	Golden Eagle	E		I	2Y	I	I	E or Y	I	1Y	1Y
7	Red-tailed Hawk	I		I	-	E	I	E or Y	I	E or Y	1Y
8	Red-tailed Hawk	4Y		I	I	E	I	E or Y	I	I	I
9	Common Raven	I		I	I	I	I	I	I	E	2Y
10	Red-tailed Hawk	I		I	I	I	I	I	I	I	I
11	Nest Gone										
12	Red-tailed Hawk	I		I	I	E	1Y	I	I	I	I
13	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	I
14	Unknown	I		I	I	I	I	I	I	I	I
15	Unknown	I		I	I	I	I	I	I	I	I
16	Great Horned Owl	I		I	I	E	2Y	I	I	I	I
17	Great Horned Owl	I		I	I	I	I	I	I	I	I
18	Red-tailed Hawk	I		I	I	I	I	1Y	I(GHO)	I	I
19	Great Horned Owl	1Y		I	I	I	I	I	I	I	I
20	Unknown							I	I	Packrats	
21	Not on map										
22	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	2Y
23	Not on map										
24	Red-tailed Hawk	I		I	I	I	I	I	I	Packrats	
25	Great Horned Owl	I		I	I	I	I	I	I	Packrats	
26	Unknown	I		I	I	I	I			Nest Gone	
27	Red-tailed Hawk	I		I	I	I	I	E or Y	I	I	I
28	Golden Eagle	1Y		I	I	I	I	I	I	I	I
29	Unknown	I		I	I	I	I	I	I	I	I
30	Red-tailed Hawk	2Y		I	I	I	I	I	I	I	I
31	Unknown	I		I	I	I	I	I	I	I	2Y RTH
32	Great Horned Owl	2Y		2Y	-	I	I	I	I	I	I
33	Unknown	I		I	I	I	I	I	I	I	I
34	Unknown	I		I	I	I	I	I	I	I	I
35	Unknown	I		I	I	I	I	I	I	I	I
36	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	I	I
37	Unknown	I		I	I	I	I	I	I	I	I
38	Raven	I		I	I	I	I	E or Y	Y	I	E or Y
39	Golden Eagle	1Y		I	I	I	I	I	I	I	I
40	Great Horned Owl	I		I	I	E	2Y	2Y	I	I	I
41	Unknown	I		I	I	I	I			Nest Gone	
42	Unknown	I		I	I	I	I	I	I	I	I
42a	Red-tailed Hawk	-		-	2Y	I	I	E or Y	I(GHO)	I	I
43	Great Horned Owl	2Y		I	I	I	I	I	I	I	I
44	Unknown	I		I	I	I	I	I	I	I	I
45	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	I	2Y
46	Red-tailed Hawk					E	I	E or Y	I	I	I
47	Unknown					I		I	I	I	I
48	Great Horned Owl							E	I	I	I
49	Red-tailed Hawk							E	I	I	I
50	Magpie									I	I
51	Red-tailed Hawk									I	1Y
52	Unknown									I	I

Code:

I = inactive nest
E = adult bird observed in an incubating posture; presumed to be incubating eggs.
(2) Y = number of young observed in the nest.
E or Y - adult bird observed in an incubating posture; due to time of year, assumed to be either incubating eggs or brooding very young chicks.

C-b. Raptor nesting has varied over the years from as low as four to as high as fifteen active nests. A note of interest, in this year's results there were no great-horned owls observed nesting in the area, although several owls were seen on the Tract during 1980. If great-horned owls are again absent from the 1981 nesting census, then a more intensive monitoring may be initiated.

8.5.3.6 Conclusions

Developmental activities on C-b Tract seems to be having little affect on raptors nesting in the study area.

8.6 Aquatic Ecology

8.6.1 Benthos

8.6.1.1 Introduction and Scope

The benthic macroinvertebrate community is an important component of the stream ecosystem. These organisms process and convert organic material into animal tissue, which is thereby available to higher trophic levels such as insectivorous fishes. For some time, macroinvertebrates have been recognized as valuable indicators of water quality (Kolkowitz and Marsson 1909; Hynes 1960; Cairns and Dickson 1973).

8.6.1.2 Objectives

The purpose of this investigation is to infer water quality and bioproductivity from macroinvertebrate taxa present.

8.6.1.3 Experimental Design

Benthic macroinvertebrate sampling stations located in Piceance Creek (Figure 8.6.1-1) are the same as the current periphyton collection stations. Six collections were obtained at approximately one month intervals between May and October, 1980. C.B. staff biologists used a standard Surber sampler to provide three replicates from each station per sampling date. Each replicate was placed in a labeled container, preserved with 10 percent formalin on site, and mailed to Mariah Associates' Aquatics Laboratory in Laramie, Wyoming for further processing and analysis.

Upon arrival, the samples are washed over a fine mesh sieve (U.S. No. 60). Organisms are separated from debris and placed in vials of 80 percent ethyl alcohol. Identification and enumeration are accomplished with the aid of a Bausch and Lomb Stereo Zoom 7 (5x-210x) dissecting microscope. Whole oligochaete and chironomid head capsules are mounted in Hoyers cleaning and mounting medium and identified with the use of a Wild Heerbrugg microscope at a magnification of 200x or 400x. Identification of organisms is based primarily upon Usinger (1956), Edmondson (1959), Wiggins (1977), Edmunds et. al. (1976), Baumann et. al. (1977), and Pennak (1978). Organisms are identified to the lowest possible taxon. These identifications are then verified by Dr. James Gore, Water Resource Institute, University of Wyoming, Laramie, Wyoming.

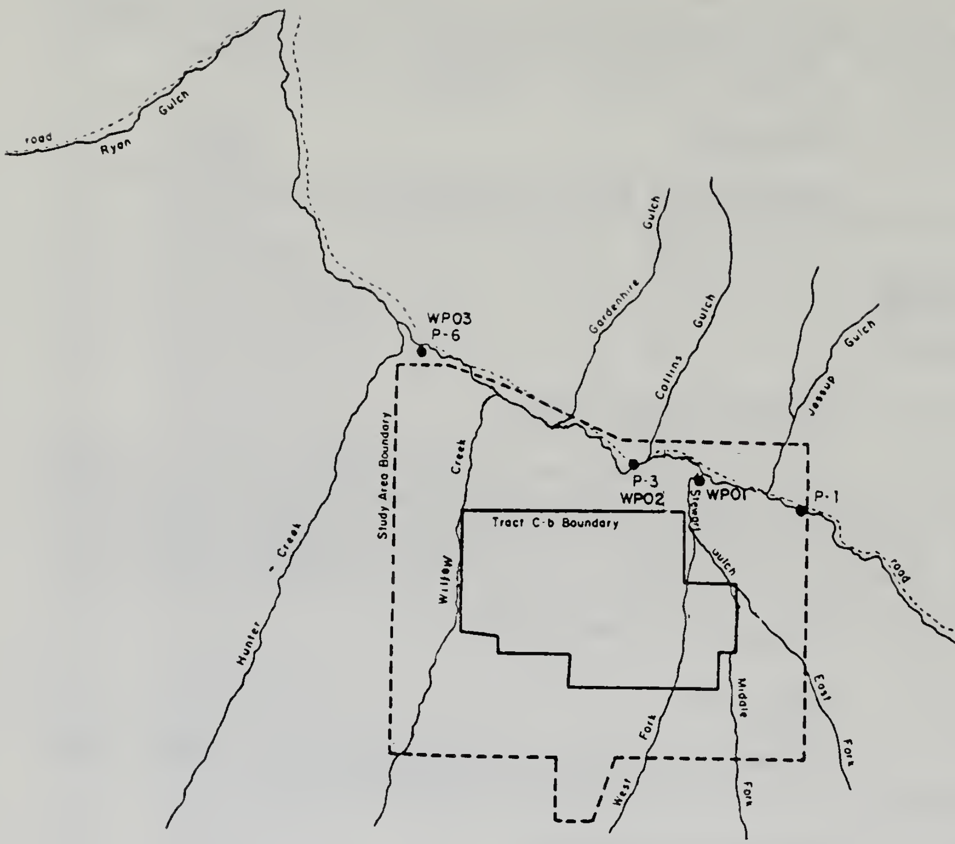


FIGURE 8.6.1-1

BENTHIC MACROINVERTEBRATE AND PERIPHYTON SAMPLING STATIONS

An index to species diversity is provided for each sample location. This index is based on the Shannon-Weiner function from the field of information theory (Margalef 1967; Lloyd and Ghelardi 1964; Pielou 1966). As a diversity index for community analysis, the function describes the average degree of uncertainty of predicting the species of a given individual picked at random from the community. This uncertainty and the index increase both as the number of species increases and as the individuals are distributed more and more equitably among species already present. The general formula for this index is as follows:

$$H = \sum p_i \log_e p_i$$

where p_i = decimal fraction of total individuals belonging to the i^{th} species.

The index varies from a value of 0 for habitats containing a single species to values of four or five for communities containing many species, each with a small number of individuals. The Shannon-Weiner species diversity index may be used to compare community composition data from a variety of sources. Differences in diversity may be expected for communities at different stages of succession, in different habitats or at different times of the year. In this case, drastic changes in macroinvertebrate diversity during project development could be indicative of increased stream sediment loads or some other project-related disruption of the chemical-physical nature of the study area aquatic systems.

8.6.1.4 Methods of Analysis

The following data are tabulated:

1. Species identification
2. Density (organisms/m^2)
3. Relative abundance
4. Shannon-Weiner diversity index
5. Maximum diversity
6. Evenness (a similarity parameter)
7. Analysis of variance

By comparing seasonal trends from 1980 and the previous years, it may be possible to elucidate the effects of the project upon the benthos of Piceance Creek. Since the data from the USGS are not available or are not in a form suitable for comparison at this time, statistical analyses are restricted to the data from the current year.

Analysis of variance is employed to determine whether external factors had an unequal influence upon macroinvertebrate densities among stations during 1980. A 3 x 6 factorial design is used to test the null hypothesis that there are no significant changes in macroinvertebrate densities among stations over time. The presence of a significant interaction term disproves this hypothesis. Density values are $\log_{10}$ transformed to reduce heterogeneity of variance associated with benthos counts. Descriptions of these methods are found in Snedecor and Cochran (1967).

8.6.1.5 Discussion and Results

Benthic macroinvertebrates were collected at three Piceance Creek stations (Figure 8.6.1-1). Descriptions of these stations are presented in Table 8.6.1-1. A total of 40 taxa were collected and identified during the 1980 study period. Species identification, density, and relative abundance are presented in the January 1981 Data Report. Evenness, the Shannon-Weiner diversity index and the number of taxa per station for each collection date are presented in Table 8.6.1-2. Similarly, mean total densities are presented in Table 8.6.1-3.

Several trends in the 1980 benthic macroinvertebrate communities are apparent. Samples from the upper Piceance Creek at Stewart and Middle Stations tended to be more diverse and to have a greater number of taxa than did the ones from the lower Hunter Station. Oligochaeta and Chironomidae increased while Ephemeroptera decreased in relative abundance from Stewart to Hunter Stations. Plecoptera were never very abundant, with only Alloperla and other Chloroperlidae being found. Although Trichoptera were present at all stations, more species were collected from Stewart and Middle Stations than from Hunter Station. The macroinvertebrate community of Piceance Creek is generally low in numbers of species, and reflects the harsh physical environment common to streams in the Piceance Basin of Colorado (Gray and Ward 1978).

The results of the statistical analysis of benthic macroinvertebrate densities indicate the existence of a highly significant interaction term ($P < 0.01$). Therefore, an external factor is having a disproportionate influence among stations during the sampling season. In order to evaluate whether Tract C-b development may have been responsible for the apparent disruption of the benthic fauna, the results of this investigation were compared to previous studies of Piceance Creek. The 1974-1976 C.B. baseline study (C-b Shale Oil Venture et. al. 1977), as well as the study by Gray and Ward (1978), provide site specific pre-development data which may be compared to current results. While these data are not in a form allowing statistical comparison to the 1980 data, comparisons of general trends in taxonomic composition, density and diversity are possible.

In 1980, 28 taxa were collected from Stewart Station. Ephemeroptera was the most abundant group in May and June. Chironomidae was the dominant family in August, while members of the Haplotaxida were abundant in early September. Of the latter encountered, Naididae was the dominant family and Tubifex tubifex was numerous. Late September samples were dominated by Ephemeroptera. Trichoptera were also abundant and increased in numbers to dominate the October samples. At Stewart Station, the mean relative abundance for the dominant 1980 groups are Ephemeroptera 34 percent, Diptera 34 percent, and Oligocnaeta 18 percent. During the 1974 through 1976 baseline study in the vicinity of Stewart Station, Ephemeroptera comprised 20 percent of the fauna, Diptera 32 percent and Oligochaeta 43 percent. From August 1975 to July 1976, Gray and Ward (1978) found Ephemeroptera to be 36 percent of the fauna at the Piceance Creek site just upstream from Stewart Station . Diptera and Oligochaeta comprised 16 percent to 34 percent of the fauna, respectively. From August 1976 to April 1977, Ephemeroptera were 30 percent of the fauna, Diptera 12 percent and Oligochaeta 40 percent (Gray and Ward 1978).

TABLE 8.6.1-1

DESCRIPTION OF MACROINVERTEBRATE SAMPLING SITES ON PICEANCE CREEK, MAY, 1980

Sample Station Location	Creek	Site Description	Substrate Type[1/]	Mean Depth (in)
Stewart Station	Piceance	Grass/low shrub/pasture	30% rubble 50% gravel 20% silt and sand	8
Middle Station	Piceance	Grass/low shrub/pasture Small waterfall at upper end of station, major irrigation diversion above small waterfall	45% rubble 40% gravel 5% silt and sand	5
Hunter Station	Piceance	Grass/low shrub/pasture	10% rubble 50% gravel 40% silt and sand	8

1/ Rubble (64-256mm); Gravel (2-64mm); Sand (0.06-2.0mm); Silt (0.004-0.6mm) (Adapted from Cummins 1962)

TABLE 8.6.1-2

SHANNON-WEINER DIVERSITY INDEX (J), EVENNESS (E)
AND NUMBER OF TAXA (S) OF THE BENTHIC MACROINVERTEBRATE
SAMPLES COLLECTED FROM PICEANCE CREEK,
MAY THROUGH OCTOBER 1980, TRACT C-b

	Stewart Station			Middle Station			Hunter Station		
Date	J	E	S	J	E	S	J	E	S
May 19, 1980	1.24	0.90	4	1.86	0.85	9	0.40	0.25	5
June 27, 1980	1.57	0.63	12	0.50	0.26	7	1.72	0.75	10
August 1, 1980	1.63	0.65	12	1.47	0.82	6	0.71	0.44	5
September 2, 1980	1.70	0.71	11	2.51	0.85	19	1.38	0.63	9
September 29, 1980	1.31	0.54	11	0.66	0.30	9	1.27	0.65	7
October 29, 1980	1.98	0.73	15	2.31	0.77	20	1.64	0.74	9

TABLE 8.6.1-3

MEAN DENSITIES OF THE BENTHIC MACROINVERTEBRATE SAMPLES
COLLECTED FROM PICEANCE CREEK,
MAY THROUGH OCTOBER 1980,
TRACT C-b (ORG/M^2)

Date	Stewart Station	Middle Station	Hunter Station
May 19, 1980	22.2	74.1	1851.9
June 27, 1980	374.1	822.2	111.1
August 1, 1980	400.0	1766.7	218.5
September 2, 1980	1837.0	803.7	222.2
September 29, 1980	1040.7	733.3	629.6
October 29, 1980	588.9	1351.9	429.6

Diversity indices for Stewart Station during the 1980 sampling season were low and ranged from 1.24 in May to 1.98 in October (Table 8.6.1-2). Similar diversity values occurred during baseline studies (September 1974 through November 1975). Gray and Ward (1978) observed a density range of 0.84 to 3.38 between August 1976 and April 1977 with a median of 2.84.

In 1980, 36 taxa were collected from Middle Station. Of this total, Tubifex tubifex was collected on every sampling date and was the most abundant species over the entire sampling period. Haplotaxida was the most abundant group during June and late September, while Chironomidae dominated the June and October samples. Diamesa species was the most abundant Chironomid in June, while Orthocladius dominated the dipteran family in October. Early September samples were dominated by the oligochaete Haplotaxidae, the Ephemeroptera and the Diptera.

The mean relative abundance for the major groups in 1980 were Oligochaeta 36 percent, Ephemeroptera 6 percent, and Diptera 44 percent. Diversity indices for Middle Station during the 1980 sampling season were erratic ranging from a low of 0.50 and 0.66 in June and late September to 2.51 in early September (Table 8.6.1-2). Diversity at this station is directly influenced by the irrigation diversion located immediately upstream. The low density values in late September were probably the result of the complete diversion of water above the station. On September 29, 1980 Middle Station was a small pool of water. Therefore, only organisms such as Tubifex tubifex which do not require a current could survive. Since Middle Station was introduced into the sampling program during the 1979 season, comparisons to previous years cannot be made. Macroinvertebrates were not sampled at this station during 1979.

In 1980, 22 taxa were collected at Hunter Station. Of this total, Tubifex tubifex was found in all but the late September samples. Haplotaxida was the most abundant group collected on every sampling date except October. Of the Haplotaxida encountered, Limnodrilus hoffmeisteri was the most abundant in the May samples. Tubifex tubifex was the dominant species in June as well as in early September. Limnodrilus hoffmeisteri, Baetis sp. and Ephemerella inermis were the dominant species in late September. The chironomids were the dominant group in October with Orthocladius being the most numerous genus.

Oligochaeta comprised 58 percent of the fauna in 1980, Ephemeroptera 12 percent, and Diptera 29 percent. During baseline studies (1974 through 1976), Oligochaeta were 47 percent, Ephemeroptera 20 percent, and Diptera 29 percent of the fauna at Hunter Station. The PC-4 Station of Gray and Ward (1978) was located near Hunter Station. Oligochaeta were 34 percent of the fauna between August 1975 and July 1976, and 59 percent between August 1976 and April 1977. Similarly, the Ephemeroptera were 46 percent and 10 percent, while the Diptera were 18 percent and 27 percent.

Diversity indices for Hunter Station during 1980 were low, ranging from 0.40 in May to 1.72 in June (Table 8.6.1-2). Similar values were recorded during baseline studies (1974 through 1976) where species diversity indices ranged from 0.44 in November 1974 to 1.82 in July 1975. Diversity

values from Gray and Ward (1978) ranged from 1.10 to 3.36 with a median of 1.26 for the months of August 1976 to April 1977.

Taxonomic composition varied only slightly between current and previous studies. Gray and Ward (1978) reported that density, diversity and biomass decreased from upstream to downstream. They also attributed the differences between stations to the influence of agriculture (irrigation withdrawals), spring-fed tributaries and ground water inflow. While fewer taxa and lower densities were found in 1980 than in the study by Gray and Ward (1978), these trends were probably due to difference in sampling year and to the fact that sampling was not conducted throughout 1980. However, the 1980 increase in the relative abundance of Oligochaeta such as *Tubifex tubifex* and *Limnodrilus hoffmeisteri*, and Chironomid such as *Orthocladius* species and *Diamesa* species at Middle and Hunter Stations may indicate an increase in siltation at these locations.

8.6.2 Periphyton

8.6.2.1 Introduction and Scope

Sensitivity of periphyton to changes in their environment has been well documented (Cholnoky 1968; Lowe 1974; Whitton 1975; Patrick 1977). Species composition and relative abundance of the total periphyton community and key periphyton species can provide good indicators of potential project effects on Tract C-b vicinity aquatic systems. Not only are periphyton amenable to sampling techniques which provide a good quantitative data base for identifying changes quickly and accurately, but they are also attached forms which cannot swim away from an adverse situation and return when conditions become more suitable for their existence. Many algal generation times are measured in hours or days rather than months or years. Thus, the study of periphyton communities should be an integral part of every aquatic monitoring program.

8.6.2.2 Objectives

The purpose of this investigation is to infer changes in water quality by examining algal bioproductivity.

8.6.2.3 Experimental Design

The 1980 periphyton sampling stations located in Piceance Creek are identified on Figure 8.6.1-1 as WP01 (Stewart Gulch near USGS Station WU07), WP02 (Middle Station) and WP03 (Hunter Creek near USGS Station WU61). Station WP01 was moved in 1977 from a baseline location of P-1 farther upstream, to its current position as a control station above development impact.

Periphyton is collected from artificial substrates (glass slides) at each station during every sampling period. The glass slides are incubated in the water for at least 21 days. Nine slides are collected from each station, placed in individual cytomailers and preserved with four percent formalin. Three of the nine slides are used for taxonomic identification and

enumeration, three for biomass determinations and three are extra slides in case any of the others become damaged. The cytomailers are sent to Mariah Associates' Aquatics Laboratory in Laramie, Wyoming. All field procedures are executed by C.B. personnel.

Five collections were obtained during the period of June through October 1980. A different type of slide holder was initiated into the program on July 2, 1980. The original type was also retained in order to compare the results from both kinds. Nine slides from each periphytometer were collected on August 1, 1980 and for the remainder of the 1980 study period. Biomass determinations and periphyton taxonomic identification and enumeration were performed on the August 1, 1980 collections. Only biomass determinations were performed on the collections from the old sampler for the remainder of the year.

Upon arrival, the biomass is removed from the slides with a razor blade, and the scrapings placed in separate crucibles to be dehydrated in a drying oven at 105 to 110°C. Samples are then cooled to room temperature in a dessicator and weighed to the nearest 0.0001 g (gross dry weight). After ashing in a muffle furnace at 450°C for approximately four hours, the samples are rewet upon cooling to replace their water of hydration, redried to a constant weight at 105 to 110°C and weighed to the nearest 0.0001 g (gross ash weight). Ash-free dry weight is obtained by subtracting gross ash weight from gross dry weight since the evaporating dish tare is assumed to be identical for the two weights.

Ash-free dry weight biomass is calculated according to the following equation:

$$\text{biomass (mg/cm}^2) = \frac{Wd - Wa}{As}$$

where: Wd = dry weight plus tare, mg
Wa = ash weight plus tare, mg
As = area scraped from slide, cm^2

Algae other than diatoms are identified directly from the slides with 200x or 400x magnification. The periphyton are then scraped from each slide with a razor blade and placed into separate jars. The contents of each jar is standardized at a volume of 100 ml by the addition of distilled water when necessary, after which it is thoroughly mixed in a blender for one minute. A single 1 ml aliquot is removed from each jar and diluted to a known volume with distilled water. A second 1 ml aliquot is withdrawn from the diluted subsample and placed in a Sedgwick-Rafter counting cell. With a 20x objective, the numbers of organisms are counted in a minimum of two lengthwise strips. The total number of diatoms is determined without identification to the generic or species level. Counts are also completed for the remaining individuals representing other algal divisions. Colonies and each 50 um filament section are considered as single units. The quantitative determination obtained

with this method is then expressed as:

$$\text{No. Cells/mm}^2 = \frac{C \times 1000\ \text{mm}^2 \times V \times DF}{L \times W \times D \times S \times A}$$

where: C = number of cells counted (tally)
V = sample volume, ml
DF = dilution factor
L = length of strip, mm
W = width of a strip (Whipple grid image width), mm
D = depth of a strip (Sedgwick-Rafter cell depth), mm
S = number of strips counted
A = area of substrate scraped, mm^2 (Weber 1973)

To identify a diatom species and its relative abundance within the diatom flora, 10 ml are removed from the initial blended sample and centrifuged at 3000 rpm for 20 minutes. The supernatant is removed and the pellet resuspended in 30 percent hydrogen peroxide for a minimum of three days while the organic matter is oxidized. This mixture is centrifuged again for 20 minutes and the pellet resuspended in distilled water. Several drops of the second resulting mixture are placed with a disposable pipet onto a No. 1 25 mm sq. cover glass. The sample is dried on a hot plate at 95°C. As soon as the sample is dry, the temperature of the hot plate is increased to 570°C in order to drive off all remaining organic matter. A labeled microscope slide is placed on a moderately warm hot plate, and a drop of Hyrax Mounting Medium added to the center of the slide. The cover glass is then placed face-down on the drop of Hyrax. After the toluene evaporates from the Hyrax, the slide is removed from the hot plate and allowed to cool. Identification and relative abundance of diatoms is then determined with the use of an oil immersion objective. Counting is stopped when a minimum of 100 individuals of the most common diatom is attained. The total number of diatoms as well as the number of each diatom species is used to calculate relative abundance. The percent composition of every diatom species is multiplied by the total diatom density determined in the Sedgwick-Rafter count to yield the density of each of these species (Weber 1973). Computerized data analysis is used to demonstrate taxonomic composition, and to calculate density, evenness and the Shannon-Weiner diversity index.

8.6.2.4 Method of Analysis

The following data are tabulated:

1. Species identification
2. Total taxa by sample and station
3. Density (organisms/mm^2)
4. Relative abundance
5. Shannon-Weiner diversity index
6. Analysis of variance
7. Maximum index
8. Evenness
9. Biomass (mg/cm^2) per sample

The Shannon-Weiner index along with the actual number of species observed is the most useful measure of diversity (Hutchinson 1975). The relative abundance of certain indicator species may disclose the potential impact of oil shale development on the periphyton community. In this analysis, the following hypotheses are tested:

H_0 = No significant change exists in the periphyton communities over time.

H_0 = No significant difference exists in the periphyton communities at the control station vs. the development stations from baseline data, recognizing the differences during baseline.

Analysis of variance is used to analyze biomass and periphyton abundance. The data are $\log_{10}$ transformed to reduce inequality of variance within samples. In many cases, especially with biological data, without a transformation there is too much within sample variability which leads to a loss of power to test various hypotheses. Bartlett's test of inequality of variance is used to determine whether the transformation is successful. A factorial design (Snedecor and Cochran 1967; Weber 1974) is used to detect any impact possibly caused by oil shale development. Although the factorial analysis of variance is able to detect changes even though differences existed before any developmental impact, it is unable to separate two different impacts. Therefore, a significant difference is based on statistical analysis and professional judgment. When a significant difference is determined to exist, the water collected on the particular sampling date is analyzed for selected chemical and physical parameters.

Since a second type of periphytometer was used in the aquatic program as of July 2, 1980, comparisons of each type were conducted for the remainder of the sampling season. On the first sampling date following the initiation of the new type, comparisons of biomass, density and relative abundance from the two types were performed. The major difference between them was in the amount of accumulated biomass. Therefore, this parameter was used for comparison of the two periphytometers for the rest of the 1980 season. A 2x3x3 factorial design was used to detect differences between the two biomass samplers. Methods of analysis are described in Snedecor and Cochran (1967).

8.6.2.5 Discussion and Results

A total of 148 taxa were identified from Stewart, Middle and Hunter Stations in Piceance Creek from artificial substrate (glass slides) samples collected during June, August, September, and October, 1980 (See January 1981 Data Report). This total comprised of 117 diatoms (Bacillariophyta), 19 green algae (Chlorophyta), 1 yellow-brown alga (Chrysophyta), 7 blue-green algae (Cyanophyta), 3 euglenoids (Euglenophyta), and 1 red alga (Rhodophyta). Lists of the taxa observed according to their months and locations of occurrence and dominance during the study and species diversity and biomass data for 1980 are provided in the January 1981 Data Report.

On July 2, 1980 a different type of periphytometer was initiated into the aquatic monitoring program. Since the new sampler can survive the fluctuating conditions of Piceance Creek better than the type used in previous years, the latter will eventually be phased out of the program. On the first collection date following the introduction of the second periphytometer, glass slides for taxonomic identification and enumeration, and for biomass determinations were collected from each type of sampler. Although differences in density and biomass were apparent, the relative abundance of diatom species from the two samplers was similar (Table 8.6.2-1). Therefore, biomass was selected as the parameter which could best delineate the differences between the two periphytometers. The biomass from each type was compared on August 1,

TABLE 8.6.2-1

RELATIVE ABUNDANCE OF THE DOMINANT DIATOM SPECIES COLLECTED ON AUGUST 1, 1980 FROM THE TWO TYPES OF PERIPHYTOMETERS

	Old-Style Periphytometer		New-Style Periphytometer	
	Taxon	% Composition	Taxon	% Composition
Stewart Station	*Navicula viridula*	25	*Navicula viridula*	25
	Navicula secreta var. *apiculata*	13	*Navicula secreta* var. *apiculata*	13
	Nitzschia dissipata	10	*Nitzschia dissipata*	20
	Nitzschia frustulum	7	*Nitzschia frustulum*	9
Total Percent of the Diatom Flora		55		67
	Diatoms were 99.82% of the algal community		Diatoms were 99.84% of the algal community	
Middle Station	*Navicula viridula*	29	*Navicula viridula*	30
	Navicula secreta var. *apiculata*	20	*Navicula secreta* var. *apiculata*	19
	Nitzschia dissipata	4	*Nitzschia dissipata*	4
	Nitzschia frustulum	4	*Nitzschia frustulum*	3
	Nitzschia palea	11	*Nitzschia palea*	14
Total Percent of the Diatom Flora		68		70
	Diatoms were 99.60% of the algal community		Diatoms were 97.37% of the algal community	

Table 8.6.2-1 (continued)

	Old-Style Periphytometer		New-Style Periphytometer	
	Taxon	% Composition	Taxon	% Composition
Hunter Station	*Navicula viridula*	52	*Navicula viridula*	67
	Navicula secreta var. *apiculata*	11	*Navicula secreta* var. *apiculata*	9
	Nitzschia dissipata	5	*Nitzschia dissipata*	5
	Nitzschia frustulum	5	*Nitzschia frustulum*	3
	Nitzschia palea	3	*Nitzschia palea*	3
	Total Percent of the Diatom Flora	76		87
	Diatoms were 99.90% of the algal community		Diatoms were 99.55% of the algal community	

September 29, and October 29, 1980. A significant ($P < 0.01$) difference was found, with the new sampler yielding an average of 26.2 percent more biomass than the old one. On this basis, data collected with the old type in past sampling years can be converted to equivalent new type values by employing a multiplication factor of 1.362. Since a comparison of only three collection dates may not be adequate, both periphytometers should be used during the 1981 study period.

Since the new periphytometer was not in use during June 1980, comparisons of densities from this month to the values from other dates are not possible. The densities from the remaining collection dates were obtained from glass slides incubated on the new sampler. Therefore, density comparisons are restricted to these dates. Periphyton density variations did not occur during the 1980 study period. Maxima for Stewart and Middle Stations occurred in August and October. Maxima for Hunter Station occurred in early September and October. Similar maxima densities for Stewart and Hunter Stations occurred on September 29, 1980. A relatively high density also existed at Middle Station on that date. Stewart and Hunter Stations had similar surface flows of 1.5 ft./sec. and 1.0 ft./sec., respectively, but just above Middle Station, Piceance Creek was completely diverted for irrigation five days prior to the September 29, 1980 sampling. At this time, Middle Station was a small pool with a depth of four to five inches. Since the scouring effect of the current was removed, periphyton attained higher densities on the glass slides. Achnanthes minutissima and Cocconeis placentula were the dominant algae present. These two diatoms are commonly found in streams and rivers but reach maximum populations in littoral periphyton found at the bottom of pools for example (Brown and Austin 1973). Increased density at all stations on October 29, 1980 was probably due to the fall maximum of diatoms which typically dominate the winter flora of the streams (Hynes 1970).

Throughout the six month study period, diatoms numerically dominated the periphyton communities accounting for 89 percent to 99.98 percent of the total relative abundance of all algae. Seasonal variation in algal relative abundance is apparent. While Navicula and Nitzschia species were the dominant genera present at all stations in June and August 1980, Achnanthes species were dominant forms at all stations from September through October 1980. Nitzschia dissipata was a dominant alga at Stewart and Hunter Stations but not at Middle Station on September 2, 1980. Cocconeis placentula and Achnanthes minutissima were codominants at Middle Station on this date. On September 29, 1980 the diatom flora was comprised primarily of Achnanthes sp. and Cocconeis sp. at all three stations. Navicula species which were dominant early in the study period began to reestablish their importance in the algal communities on October 29, 1980.

Based on comparison of 1980 sampling results to periphyton analysis of previous years (1978 C-b Annual Report; and 1979 C.B. Annual Report) annual variations also seem to be occurring in Piceance Creek. Achnanthes species dominated the periphyton in all samples collected in 1979. Seasonal variations in dominance were noted for Cocconeis placentula, Fragilaria vaucheriae, Nitzschia species, and Gomphonema species in 1979. Seasonal variations for 1978 were similar to the trends in 1980. However, return to dominance of the Navicula species in 1978 was not observed.

Periphyton analysis data for 1974-1976 is qualitative only (C-b Shale Oil Venture et. al. 1977). No information is available for comparison of relative abundance and dominance. Since Middle Station was introduced into the monitoring program in 1979, a comparison of the three stations can only be conducted between 1979 and 1980. Stewart and Hunter Stations can be compared from 1977 to 1980.

In the vicinity of Stewart Station, there appears to be considerable annual variation in the periphyton community.

In the late spring 1980, Navicula viridula, Navicula secreta var. apiculata, Nitzschia fonticula, Nitzschia palea and Surirella ovata were the dominant taxa; while in 1979, Achnanthes minutissima, Navicula viridula and Nitzschia species were dominant. The 1978 dominant forms were Achnanthes minutissima, Navicula secreta var. apiculata, Nitzschia acicularis and Nitzschia species.

Dominant taxa in the summer of 1980 were Achnanthes lanceolata var. dubia, Achnanthes minutissima, Cocconeis placentula, Navicula secreta var. apiculata, Navicula viridula, Nitzschia dissipata and Nitzschia frustulum. The same taxa were dominant in the summers of 1978 and 1979 except the Nitzschia species which were not identified below the generic level.

In the fall 1980, the same algae were dominant as in the summer with the exception of Nitzschia frustulum which decreased in importance. Gomphomena olivaceum became an important species on October 29, 1980. It is usually considered a winter form (Hynes 1970). In 1978 and 1979, the dominant algae were Achnanthes lanceolata, Achnanthes minutissima and Cocconeis placentula. These organisms are typically the first algae to colonize glass slides (Cholnoky 1968) which may be an indication that the artificial substrates were not incubated long enough in the fall of 1978 and 1979 or that severe scouring occurred. Dominant diatoms of 1977 were similar to the flora observed in 1980. The chantransia-phase of Batrachospermum was observed at Stewart Station in October 1980. This alga grows only in or near springs (Ward and Dufford 1979). Since Middle Station was initiated in 1979, only comparisons of that year and 1980 are possible.

In the summer of 1980, Navicula secreta var. apiculata, Navicula viridula, Nitzschia acicularis, Nitzschia holsatica, Nitzschia palea and the palmella stage of a green alga comprised the majority of the algae present at Middle Station. Achnanthes lanceolata, Achnanthes minutissima, Gomphonema parvulum, Navicula viridula, Nitzschia species and Cladophora species were the dominant flora in 1979. Cladophora species was present in 1980, but not in the same numbers as in 1979.

The dominant algae during September of 1979 and 1980 were Achnanthes lanceolata, Achnanthes minutissima and Cocconeis placentula. This flora may again indicate that the glass slides were not incubated long enough in the creek or that severe scouring occurred prior to their collection. Also, environmental conditions at Middle Station on September 29, 1980 were conducive to the establishment of a pond flora. These algae reach their maximum development in littoral habitats.

The October 1979 flora was similar to the periphytic community of September 1979. However, Navicula secreta var. apiculata and Navicula viridula increased in numbers between the two months. The October 1980 dominant algae were Achnanthes minutissima, Cymbella minuta var. silesiaca, Navicula cryptocephala var. veneta, Navicula secreta var. apiculata and Navicula viridula.

In the vicinity of Hunter Station, some annual and seasonal variation was apparent.

In late June 1980, Navicula viridula, Navicula secreta var. apiculata, Nitzschia holsatica and Nitzschia palea dominated the periphyton community. The early July 1979 flora was comprised mainly of Navicula viridula, Gomphonema parvulum and Nitzschia species. The June 1978 algal dominants were Achnanthes lanceolata var. dubia, Achnanthes minutissima, Navicula viridula, Nitzschia acicularis, Nitzschia palea and Nitzschia species.

The 1980 summer flora dominants included Achnanthes minutissima, Navicula secreta var. apiculata, Navicula viridula and Nitzschia dissipata. The 1979 algal community was similar in composition. However, Achnanthes lanceolata var. dubia, Achnanthes minutissima, Cocconeis pediculus and Cocconeis placentula comprised 73 percent of the periphyton in 1978.

The Hunter Station fall periphyton communities for 1977, 1978, 1979 and 1980 were similar. Achnanthes lanceolata var. dubia, Achnanthes minutissima, Cocconeis pediculus, Cocconeis placentula, Navicula secreta var. apiculata and Navicula viridula were the dominant species.

Most of the taxa observed during the seven year study of Piceance Creek were algae with similar environmental requirements. These taxa are common in this region and characteristic of alkaline waters (pH greater than seven) with high dissolved oxygen, relatively high inorganic material concentrations and medium organic load where oxidation is proceeding (Cholnoky 1968; Lowe 1974). Most of the taxa recorded as abundant are considered to be cold water forms.

Differences in sampling techniques and levels of taxonomic expertise may have been responsible for some of the variation observed over the years. In addition, the glass slide incubation time may not have been long enough on some sampling dates. As a result, the flora collected on these dates may have been in the phase of accumulation rather than the more stable phase of reconstruction (Hutchinson 1975). The organisms which are flat and can attach themselves directly to the substrate are usually the first to colonize glass slides. Examples include Achnanthes lanceolata, Achnanthes minutissima, Cocconeis pediculus and Cocconeis placentula. Stalk and tube-forming diatoms occur during the reconstruction phase. Cymbella species, Gomphonena species and Navicula viridula are examples of these organisms. Also, the annual differences have been due to a combination of environmental factors such as light (turbidity), temperature, flow rate, nutrients and pH. Any or all of these factors may vary on an annual basis irregardless of man-made perturbations.

Analysis of variance was used to test for significant

differences (P = 0.01 level) in total periphyton densities. All stations were significantly different from each other, as were all sampling data with the exception of August and October 1980. Statistical analysis indicates the existence of a highly significant interaction term (P> 0.01) which implies that an external factor(s) is having a disproportionate influence among stations.

No seasonal trends were apparent in the 1980 ash-free dry weight biomass productivity. In 1975, 1976, 1977, 1979 and 1980 biomass productivity tended to be higher at Stewart Station than at Hunter Station, while in 1978 the reverse was true. In 1979, Middle Station's biomass productivity was generally higher than that of Hunter Station, and Stewart and Middle Stations alternated positions throughout 1979. In 1980, biomass productivity of Middle Station tended to be higher than at the other two stations (Table 8.6.2-2).

Statistical comparisons of 1980 periphyton biomass between stations and months were accomplished using analysis of variance at the P = 0.01 level. Since the algal densities were obtained from the new periphytometer August through October 1980, the biomass data from this substrate holder was used for comparison. Each month was significantly different than the others. Stewart Station was significantly different than Middle Station which was likewise different than Hunter Station. However, Stewart Station was not significantly different than the latter.

Statistical comparisons of total species between stations and months in 1980 were accomplished using analysis of variance at the P = 0.01 level. No significant difference was found between stations. August was significantly different than the other months which were statistically similar. August also had more species of green algae (Chlorophyta), blue-green algae (Cyanophyta) and euglenoids (Euglenophyta). The maximum development of these algae occurs during the summer (Hynes 1970).

Species diversity values for 1980 are summarized in Table 8.6.2-3. Diversities at Stewart and Middle Stations were highest during the summer, but at Hunter Station they were highest in the early fall. In 1979, highest values occurred during summer months and the lowest in the fall. Diversity values in 1978 decreased steadily at Stewart and Hunter Stations between May and July but increased in August. Lowest values for both stations occurred in the fall. The extremely low density values recorded in 1978, 1979, and 1980 occurred when Achnanthes species and Cocconeis species dominated the periphyton. These genera are early colonizers of glass slides. Species diversity values are usually low during the earliest stages of colonization (Hutchinson 1975).

Since a multitude of factors such as irrigation, cattle grazing, springs and C.B. water discharge affect Piceance Creek between stations (Gray and Ward 1978; Martinson 1980), professional judgment must be employed to decide whether further water analysis may be necessary. Since significant differences existed among stations in August 1980, analyses of selected parameters were performed on the water samples. Sulfate levels were slightly above the mean concentration expected at Hunter Station, but still well within the baseline ranges (personal communication, Fred Noble, C.B. staff biologist). Therefore, the differences between the stations were compared to the August data. Since the combined magnitude of the differences in density, number of

TABLE 8.6.2-2

SUMMARY OF MEAN BIOMASS (MG/CM^2) EXPRESSED AS ASH-FREE DRY WEIGHT FOR PERIPHYTON COLLECTED AT STEWART, MIDDLE, AND HUNTER STATIONS, PICEANCE CREEK, 1980

Old-Style Periphytometer

Sample Date	Stewart Station	Middle Station	Hunter Station
August 1, 1980	0.80	0.84	0.68
September 29, 1980	0.11	0.49	0.21
October 29, 1980	0.30	0.73	0.42

New-Style Periphytometer

Sample Date	Stewart Station	Middle Station	Hunter Station
August 1, 1980	0.85	1.54	0.86
September 2, 1980	0.41	0.43	0.57
September 29, 1980	0.18	0.38	0.03
October 29, 1980	0.43	1.21	0.72

TABLE 8.6.2-3

SUMMARY OF SPECIES DIVERSITY OF THE MEAN FOR PERIPHYTON COLLECTED AT STEWART, MIDDLE, AND HUNTER STATIONS, PICEANCE CREEK, 1980

Sample Date	Stewart Station	Middle Station	Hunter Station
June 27, 1980 (old-style periphytometer)	2.275	2.833	1.553
August 1, 1980 (old-style periphytometer)	2.705	2.559	1.823
August 1, 1980 (new-style periphytometer)	2.497	2.398	1.520
September 2, 1980 (new-style periphytometer)	1.903	1.764	1.959
September 29, 1980 (new-style periphytometer)	1.771	1.571	1.915
October 29, 1980 (new-style periphytometer)	1.996	2.434	1.345

species and biomass were never greater than the August differences, no further water analysis was performed.

8.6.2.6 Conclusions

Comparisons of the 1980 benthic macroinvertebrates and periphytic algae from Stewart, Middle and Hunter Stations in Piceance Creek reveal apparent and significant differences between these communities. However, the current differences are similar to the ones observed among these stations prior to oil shale development. In addition, composition of the flora has remained fairly constant over the years. If project development were affecting the chemical composition of Piceance Creek, these changes should have been reflected by variations in algal species composition and in the relative abundance of certain indicator organisms.

Since the periphyton were grown on glass slides, increases in abrasive suspended material would have had the tendency to maintain the flora in early colonization stages. This phenomenon occurred several times during the 1980 sampling period. Another possible explanation could be insufficient incubation of the slides in the creek which prevents the development of a mature periphyton community. The latter is probably the reason for the occurrence since flora representing early colonization were noted in the collections of previous years.

Benthic macroinvertebrate taxonomic composition varied only slightly between current and previous study periods. The 1980 increase in relative abundance of oligochaetes and chironomids at Middle and Stewart Stations indicates the occurrence of increased siltation at these locations. Many factors present in the Piceance Creek watershed could have contributed to this phenomenon. Even if oil shale development were affecting the fauna of this creek, stronger influences are probably masking its effects. The major man-made perturbation seems to be irrigation. Gray and Ward (1978) attributed the variability in fauna throughout the Piceance Basin to the influences of irrigation withdrawals, cattle grazing, spring-fed tributaries and ground water inflow.

8.7 Terrestrial Studies

The terrestrial studies portion of the Environmental Baseline Program was designed to describe the predevelopment biological environment within the C-b study area and to provide baseline data to be used in monitoring changes in the biota as a result of oil shale development. Baseline parameters were selected for their usefulness in describing the existing environment on Tract C-b. Development monitoring parameters were judged to be useful because of their measurability or relatively low natural variability, and/or sensitivity to expected environmental perturbations.

8.7.1 Vegetation Community Structure and Composition

8.7.1.1 Scope

The vegetation community structure and composition studies evaluate major changes in the make-up of the major plant communities on

the Tract. Other vegetation monitoring programs provide a better means for statistically evaluating changes. The structural and compositional studies are better used for evaluating general vegetative trends. These studies are centered on the six intensive study sites established during 1974 and sampled on a three-year rotational basis. Chained pinyon-juniper rangeland Plots 1 and 2 (BJ01, BJ11, BJ02 and BJ12) were sampled in 1978, pinyon-juniper woodland Plots 5 and 6 (BJ05, BJ15, BJ06 and BJ16) were sampled in 1979, and sagebrush Plots 3 and 4 (BJ03, BJ13, BJ04 and BJ14) were sampled in 1980. The sequence will be repeated beginning in 1981.

8.7.1.2 Objectives

The objective of the community structure and composition studies is to obtain long-term data from permanently located sampling quadrats to evaluate differences in numerous species with respect to long-term trends. The productivity studies, discussed later, focus on monitoring a process; the structure and composition studies focus on performances of species within the major vegetation types.

8.7.1.3 Experimental Design

The community structure and composition studies are conducted at the six intensive study plots. Two are located in the pinyon-juniper woodland type, two in the chained rangeland type and one each in the bottomland sagebrush and upland sagebrush types. At each location a grid of 25 1.0 m^2 quadrats has been established in a permanently fenced and in an adjoining open area (a grid in each for a total of 50 quadrats for each site). Observations on the herb and ground-layer components are made in the 1.0 m^2 quadrats.

Shrubs are sampled along line-strip transects. The center posts marking the herb quadrats serve as end points of the transects, thus producing a total of 20 line-strips per grid. The herb quadrats are established on 10-meter centers. The line-strips are 10 meters long and 4 meters wide. Shrub cover estimates are obtained using a 10-meter line intercept located in the center of the line-strip. Density estimates are obtained by counting the number of individuals of each species within the line-strip. Individuals are recorded on the basis of height classes so that it is possible to obtain measures of population structure.

In the woodland plots canopy cover for tree species is recorded along the same 10-meter line intercept used for estimating shrub cover. All of the trees within the area defined by the herb quadrat grid (40 meters by 40 meters) have been tagged and numbered. Changes in tree diameter are evaluated by repeated measurement of these trees.

In addition to the six intensive study sites, a seventh site was added in 1980. This plot is located in the chained rangeland type within the area which will be irrigated. This plot was sampled in 1980 and will be sampled in conjunction with the other chained rangeland sites as long as the irrigation program continues.

The parameters being monitored in this study include: Cover and frequency for herbaceous species; cover, frequency and density for shrubs; and diameter and canopy cover for tree species.

8.7.1.4 Method of Analysis

Data from the community structure and composition studies are mainly being evaluated through use of trend analysis. Total vegetation composition changes are being evaluated by examining trends in similarity indices.

8.7.1.5 Discussion and Results

Monitoring vegetation changes through the use of permanent quadrats has several advantages. By repeated sampling of identical areas most of the variability caused by sample quadrat location can be eliminated. Also, if desired, it is possible to evaluate changes within each of the quadrats. Even though the use of permanent quadrats reduces sampling error, two sources of error remain. In visual estimation of species cover, it is very difficult to be totally consistent from year to year, even if the data are recorded by the same observer. Also, difficulties in species recognition constitute a source of error which is difficult to eliminate. This is especially true for grass species in vegetative condition. Species recognition problems are manifested in both cover and freqency data. Visual estimates affect only the cover data.

The vegetation of the upland sagebrush type is characterized by big sagebrush (Artemisia tridentata) and numerous species of perennial grasses. The type occurs primarily on upland sites where the soils tend to be deeper than on those sites which support pinyon-juniper woodlands. At Plot 3-0 (BJ13) the major species are western wheatgrass (Agropyron smithii) (100 percent frequency; 6.1 percent mean cover); prairie junegrass (Koeleria gracilis) (100 percent frequency; 2.9 percent cover); needle-and-thread grass (Stipa comata) (80 percent frequency; 2.2 percent cover); mutton grass (Poa fendleriana) (100 percent frequency; 1.5 percent cover), and Hood's phlox (Phlox hoodii) (100 percent frequency; 2.2 percent cover). Collectively, these species account for 72.5 percent of the total herb layer cover at Plot 3-0 (Table A8.7.1-1). Total herb layer cover was only 17 percent. Thirty species were encountered in the herb layer sample. Of these, seven were encountered in every quadrat. Total species density was 16.2 species per square meter.

Species composition at Plot BJ13 has changed little over the past six growing seasons (Table A8.7.1-2). The major differences which can be seen relate to uncertainty in identification of certain species groups. Perennial grasses including mutton grass, needle-and-thread grass, and a species which has been called Festuca brachyphylla in 1975 and 1976 (probably F. idahoensis) have been vegetatively confused. Frequency for needle-and-thread grass was 8 percent in 1975, 4 percent in 1976 and 80 percent in 1980, while frequency for Festuca brachyphylla was 64 percent in 1975, 96 percent in 1976 and zero percent in 1980. Mutton grass frequency values went from 64 percent in 1975 to zero in 1976, and to 100 percent in 1980. Under dry, vegetative conditions these three species have been confused and the fluctuations in frequency

relate to identification errors, rather than dramatic changes in the populations of these perennial species. A similar situation exists with the Indian paintbrush species (Castilleja lunariaefolia and C. chromosa). The fluctuation in mariposa lily (Calochortus nuttallii), however, represents a different sort of variability. In dry years this species either senesces very early or does not come up at all. In 1975, a relatively moist year, mariposa lily was observed in every quadrat. In 1976, it was not observed in any of the quadrats. In 1980, it had a frequency of 76 percent. Date of sampling, which has remained approximately the same over the six years, is important relative to the detection of this species. The general trend in mean total cover has been downward (Table A8.7.1-3). Mean herb cover was 30.4 percent in 1975, 27.8 percent in 1976 and 16.8 percent in 1980. This same trend has been noted at the other sagebrush sampling sites. Over this same time period litter cover has increased and bare soil area has decreased. Total species density (number of species per square meter) has increased slightly from 15.7 in 1975 to 16.2 in 1980.

The vegetation at Plot 3-F (BJ03) was originally very much like that at Plot 3-0. The two plots are contiguous and except for minor site differences, they were very similar and had received the same management until late 1974 when the fence was constructed around Plot 3-F. In 1980 the major species at Plot 3-F were mutton grass, prairie junegrass and western wheatgrass (Table A8.7.1-4). Major forb species include northern sweetvetch (Hedysarum boreale), Hood's phlox, and low fleabane (Erigeron pumilus). These six species account for 65 percent of the total cover. Cover by species was not recorded until 1980 so it is not possible to evaluate species cover trends. It is, however, interesting to note that cover by forb species is approximately two times greater in Plot 3-F than it is in Plot 3-0. General observations suggest that forbs are much more conspicuous in the fenced plot. Species composition at Plot 3-F has remianed stable over the last growing seasons (Table A8.7.1-5). The problems with species identification can also be seen in the Plot 3-F data. Frequencies for easily recognizable perennial forb species have remained relatively constant for each of the sampling years.

Trends for total cover in Plot 3-F are similar to those in Plot 3-0 (Table A8.7.1-3). These trends may be related to either variation in cover estimation or they may indicate an actual decrease in cover. Litter has increased in Plot 3-F from 40 percent in 1975 to 84 percent in 1980. This is likely a reflection of long-term fencing of the plot. During this same time period, litter cover has increased from 26 percent to 72 in Plot 3-0. Species density has increased from 17.8 to 18.3 species per square meter. This increase is probably well within the range of sampling error.

The bottomland sagebrush type occurs along the intermittent drainages that cross the tract. The vegetation is composed primarily of big sagebrush which grows to more than twice the height of the sagebrush in the upland sagebrush type. The understory herb layer in the bottomland type is usually sparse and low in production. The major herbaceous species at Plot 4-0 (BJ14) are Indian ricegrass (Oryzopsis hymenoides) needleand-thread grass, and western wheatgrass (Table A8.7.1-6). Mean for these three species combined was only 2.7 percent, but this amounts to more than 85 percent of the total herb layer cover. Cheatgrass (Bromus tectorm) was the most frequently encountered species and during favorable years, this species dominates the herb layer.

During 1980, it was a minor component of the vegetation. Total species density was 4.72 species per square meter. Very few changes can be seen in species composition at Plot 4-0 over the past six growing seasons (Table A8.7.1-7). The most noticeable changes in frequency have occurred with the annual forbs. Total herb cover has decreased from 17.3 percent in 1975 (a high year for cheatgrass) to only 3.9 percent in 1980. Mosses have decreased in cover while litter and bare soil have remained consistent from year to year. Species density has decreased slightly from 5.2 species per square meter in 1975 to 4.7 species per square meter in 1980.

The vegetation at Plot 4-F (BJ04) is very comparable to that, at Plot 4-0. The major herb species (Indian ricegrass, needle-and-thread grass and western wheatgrass) had a combined mean cover value of 3.4 percent which is 82 percent of the total. Cheatgrass had the highest frequency value (Table A8.7.1-8). The species composition has changed little over the past six growing seasons (Table A8.7.1-9). Annual forbs show the greatest changes. Indian ricegrass has increased slightly since 1975. Total herb cover has decreased from 14 percent in 1975 to 4 percent in 1980. This decrease may be related to the observed decrease in cheatgrass. Cover by litter and bare soil have changed slightly between 1975 and 1980 (Table A8.7.1-3). Total species density has decreased from 4.3 to 3.0 species per square meter.

Shrub layer data summaries for the big sagebrush vegetation types are presented in Tables A8.7.1-10 - A8.7.1-12. At Plots 3-F and 4-F shrub cover, and density values are comparable for the sampled years. Cover has shown a gradual increase in the fenced plots. The most striking changes in the sagebrush types have occurred at Plots 3-0 and 4-0. At Plot 3-0 big sagebrush cover and density doubled between 1976 and 1980. Some of this increase may be attributable to different researchers collecting the data; however, it appears that the amount of sagebrush at the upland open study plot is increasing. Increases also occurred at Plot 3-F, but they were not nearly as dramatic. At Plot 4-0 cover by big sagebrush increased from 29.5 percent to 47.3 percent between 1976 and 1980. During this same period, recorded density decreased from 33,500 to 18,200 individuals per hectare. These fluctuations may be related to sampling error; however, it is possible that the sagebrush cover and density are as variable as the data suggest. It will be interesting to see if the data collected in 1983 will show continued increases in cover and density, or if the data will suggest a decline.

Overall trends in sagebrush community composition are being monitored using a similarity index. By using the similarity index, it is possible to see how the communities have changed over time. Similarity was calculated using the formula:

$$S.I. = \frac{2w}{a+b} \times 100$$

where

S.I. = Similarity Index

w = Sum of the amount of the comparison parameter shared by the sites being compared

a = Sum of the amount of the comparison parameter at one sampling location

b = Sum of the comparison parameter at the other sampling location

For the purposes of comparing Plots 3 and 4 over time, herb layer species frequency was used as the comparison parameter. The similarity between Plots 3-0 and 3-F has changed very little over the past six growing seasons (Figure 8.7.1-1). The similarity between Plots 4-0 and 4-F has declined slightly (Figure 8.7.1-1) most likely as a result of the variable frequency of the annuals at this site. At Plot 3, the similarity between 3-0 and 3-F has increased approximately 5 percent and at Plot 4 the similarity between 4-0 and 4-F has decreased approximately 6 percent. Similarity was also evaluated for each of the Plots in terms of sampling date (Figure 8.7.1-2). Some of the Plots (Plots 3-0 and 4-F) showed the greatest similarity between 1976-1980. None of the plots showed the greatest similarity between 1975-1980. All of the similarity values have remained high (greater than 70 percent) over the last six years.

Irrigation Study Plot - Chained Rangeland. The species composition of the chained rangeland irrigation study plot is typical of the chained rangeland type (Table A8.7.1-13). Major species include western wheatgrass, Indian ricegrass, and mutton grass. Species density had a mean value of 8.6 species per square meter. Major shrub species include big sagebrush and samplings of Utah juniper (Juniperus osteosperma) (Table A8.7.1-14). Comparison of the irrigation study plot and other chained rangeland plots will be included in 1981 monitoring report, since the chained rangelands will be sampled in 1981.

8.7.1.6 Conclusions

No major changes have occurred in the herb layer components in either the upland or bottomland sagebrush shrubland types. Even though the exclosures have been in place for six growing seasons, the open and fenced plots still share a high degree of similarity. Shrub species composition has remained essentially the same, however sagebrush cover at both Plots 3-0 and 4-0 has shown a marked increase since 1976. The observed changed in species composition, trends in similarity index, and shrub cover and density appear to be related to natural variation or sampling error and do not appear to be related to oil shale development on the site.

8.7.2 Herbaceous Productivity and Utilization

8.7.2.1 Scope

Productivity of vegetation is intrinsically important in the operation of ecosystems on tract C-b. The amount of production and availability of food are both of consequence for animal species within the system. Any significant interruption in production may well be manifested in changes throughout the ecological system. In terms of monitoring, herbaceous production is a more convenient parameter to measure and is a reflection of the total production in any of the communities on the Tract. By monitoring the herbaceous production it is possible to evaluate yearly and site-to-site differences in productivity. The scope of the herbaceous productivity and utilization studies includes sampling on a Tract-wide basis, sampling at the intensive study sites established during the baseline studies period, and also sampling in native communities fertilized in order to increase production. The

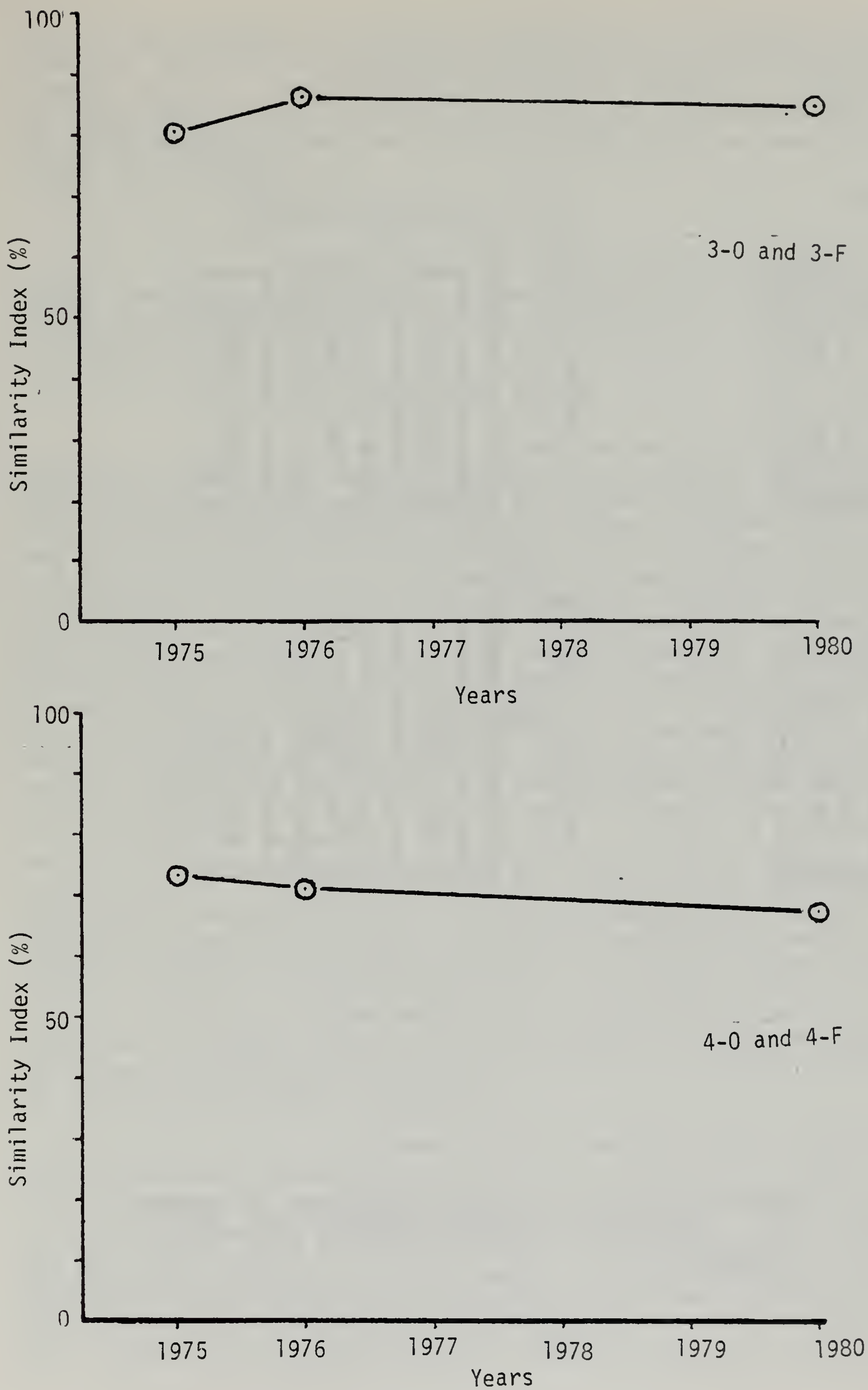


Figure 8.7.1-1 Trends in similarity index (based on herb layer species frequency) at Plots 3 and 4.

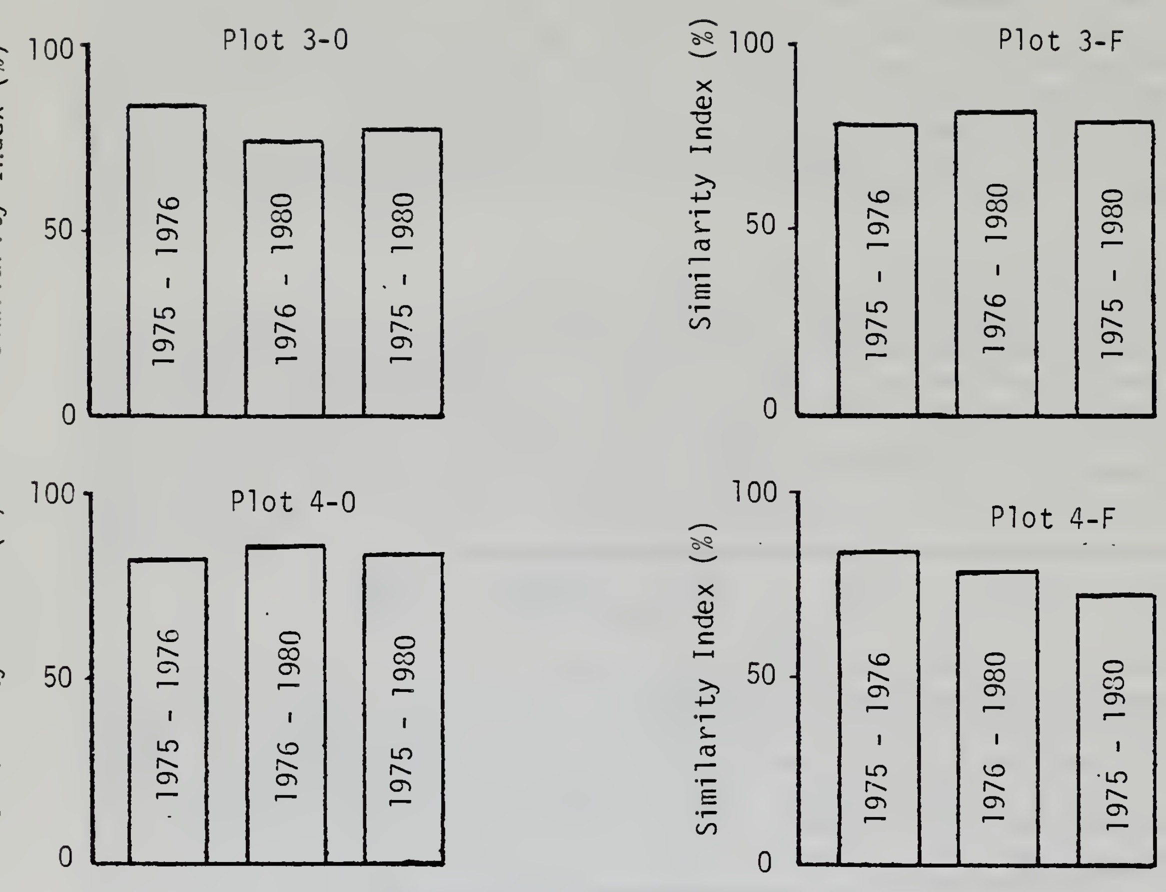


Figure 8.7.1-2 Trends in similarity index between years at intensive study Plots 3 and 4 (based on herb layer species frequency).

fertilization evaluation studies are conducted on an as-needed basis. Also, studies of possible air pollution effects north of Piceance Creek will be repeated only if it appears necessary to do so. In 1980 an irrigation program was initiated solely to control excess mine water in a portion of the chained rangeland vegetation type. Herbaceous production will be used to evaluate the effects of irrigation.

8.7.2.2 Objectives

The objectives of the productivity and utilization studies are to provide the means for measuring trends of herbaceous production related to development activities, and to evaluate any changes in herbaceous utilization.

8.7.2.3 Experimental Design

Herbaceous production and utilization are being studied on a Tract-wide basis through the use of randomly located exclosures. These exclosures (range cages) are small in size and prevent grazing by large herbivores on slightly more than one square meter of ground. Individual placement of the range cages is determined by using random coordinates on the vegetation map of the Tract. These random sites are then located in the field. Once the sampling point is located, a second comparable, nearby site is also located (usually within 5-10 meters of the first). The range cage is then randomly placed over one of the two sites. The "caged" quadrat is clipped later in the growing season in order to estimate production. The other "non-caged" site is clipped in order to provide the data necessary for evaluating the degree to which the herbaceous vegetation is utilized by large herbivores. It is important to assure that the two quadrats in the pair are comparable. Because of the inherent sparsity and heterogeneity of the herbaceous production on the Tract, it is very easy to have two quadrats located adjacent to one another and to have order-of-magnitude differences in production. It could be either caged or open areas that are so strikingly different. If the highly productive areas are always caged, it is possible for the data to misrepresent the extent of utilization, and if the open areas are consistently more productive the data would suggest an adverse caging effect. If the placement of the quadrats were totally random with respect to open and caged areas, utilization effects would be masked by the variability of the production data. For these reasons it was necessary to adopt the above mentioned design for the utilization studies. All sampling locations are randomly selected and the placement of the range cages is randomly determined. The effect of this design is to retain objectivity while minimizing the effect of production variability.

Fifteen pairs of sampling sites (range cages and open areas) are placed throughout the Tract in each of the four major plant communities (pinyon-juniper woodlands, chained pinyon-juniper rangelands, upland sagebrush shrublands, and bottomland sagebrush shrublands). The quadrats are clipped at peak season (approximately mid-late July), and all of the current year's growth is removed. Clipped samples are fractionized on the basis of species for western wheatgrass, cheatgrass and Indian ricegrass, and on the basis of life form for other perennial grasses, other annual grasses, perennial forbs, annual forbs, and half-shrubs. Caged and adjacent open areas are clipped

at the same time. Clipped samples are returned to the lab, oven dried to a constant weight and then weighed to the nearest milligram.

Production studies at the intensive study sites are being conducted using a double sampling approach. Fifty-one square meter quadrats are randomly located in seasonally fenced plots at the intensive study sites. (Fences are put up at the beginning of the growing season). The weight in grams for each of the current year's growth fractions listed above is estimated in each of the fifty quadrats. Ten of these quadrats are clipped in addition to being estimated. Once the samples have been dried and weighed, regression equations are developed for each of the species or species groups. All of the fresh estimates are then corrected to an oven dry weight on the basis of the derived equations. Data from these studies are compared with information derived during baseline periods and are also used to compare vegetation types and study sites within any given year.

The effects of fertilization and irrigation are also being monitored in the chained rangeland type. See Figure 5.2.6-2. This study was initiated in 1980 and was designed to evaluate the effects of four fertilizer treatments and two irrigation treatments. The four fertilizer treatments consist of: 1) no fertilizer, 2) no nitrate and 100 lbs/acre of phosphate, 3) 100 lbs/acre of nitrate and 100 lbs/acre of phosphate and 4) 200 lbs/acre of nitrate and 200 lbs/acre of phosphate. Each of these treatments is replicated in areas irrigated for 12 hours and 18 hours. In each of the replicated blocks, total production is evaluated using a double sampling approach. The biomass for each of the sample fractions mentioned earlier was estimated in ten 1.0 m^2 quadrats. Two of these were clipped, oven dried and weighed. Regression equations were developed based on the clipped and estimated quadrats from seven of the eight treatment blocks. The eighth block (no fertilizer; 12 hours of irrigation) was sampled using ten range cages and adjacent open areas.

8.7.2.4 Method of Analysis

Analysis of herbaceous production and utilization data is focused on five areas of comparison. These include evaluation of:

1. Differences among vegetation types during a given growing season.
2. Differences between study sites of the same vegetation type during a given growing season.
3. Differences between years within a given vegetation type.
4. Differences between fenced and open areas within a vegetation type during a given growng season.
5. Differences in production related to the addition of fertilizer and irrigation.

Total production is used as the parameter for comparison. Evaluation of differences is accomplished using trend analysis and one-way analysis of variance (F-test) to test whether or not the observed differences in means are significant. Effects of fertilizer and irrigation are evaluated using a non-nested two-way analysis of variance.

8.7.2.5 Discussion and Results

Tract-wide Range Cage Studies. The purpose for conducting the Tract-wide range cage studies is to provide more broadly based estimates of production in the major vegetation types than can be obtained from the intensive study sites. Data from these studies can be used in evaluating trends and can also be compared using statistical tests. Because of the high variability of the data, the statistical tests are not overly sensitive and differences in means need to be rather large in order to be judged significant. An attempt has been made to obtain sufficient samples to be able to detect a 20 percent difference in means with 80 percent confidence. This level of adequacy was reached in the upland sagebrush and chained rangeland communities but was not attained in the bottomland sagebrush and pinyon-juniper woodland communities. Low production and patchy distribution of individual plants tend to make the latter two communities more variable.

Herbaceous production is summarized on Figures 8.7.2-1, -2, and -3 for PJ woodlands, chained PJ and big sagebrush and tabulated in Table 8.7.2-1. Oven dry weights for range cages and adjacent open areas in the pinyon-juniper woodlands are presented in Table A8.7.2-1. Mean total production in the pinyon-juniper woodlands was 10.4 g/m^2 (93 lbs/acre). Most of the production was attributable to western wheatgrass and other perennial grasses (Table A8.7.2-2). In the non-caged areas, mean production was 10.3 g/m^2 (92 lbs/acre) suggesting very little utilization of this type by livestock. Major species in the open areas were western wheatgrass, other perennial grasses and cheatgrass.

Oven dry weights for range cages and adjacent open areas in the chained rangelands are presented in Table A8.7.2-3. During 1980 the mean total production in the chained rangeland type was 40.8 g/m^2 (353 lbs/acre). Major species were western wheatgrass and other perennial grasses (Table A8.7.2-4).

In the open areas, mean production was 33.6 (299 lbs/-acre). Utilization of chained rangelands was approximately 18 percent. Major species in the open areas were western wheatgrass, other perennial grasses and perennial forbs (Table A8.7.2-4).

Dry weight data for each of the range cages and adjacent open areas in the upland sagebrush type are presented in Table A8.7.2-5. Mean production for the upland sagebrush type was 42.8 g/m^2 (381 lbs/acre). Major species in this type include perennial grasses, perennial forbs, and western wheatgrass (Table A8.7.2-6). Mean total production for non-caged areas was 28.6 g/m^2 (255 lbs/acre) with the same species occurring as dominants. Utilization by large herbivores was approximately 33 percent.

Oven dry weight data for each of the range cages and adjacent open areas in the bottomland sagebrush type are presented in Table A8.7.2-7. Mean total production for the range cages was 27.0 g/m^2 (240 lbs/-acre) and 17.9 g/m^2 (159 lbs/acre) for adjacent open areas (Table A8.7.2-8). Major species include perennial grasses, western wheatgrass and cheatgrass. Utilization by large herbivores was 34 percent.

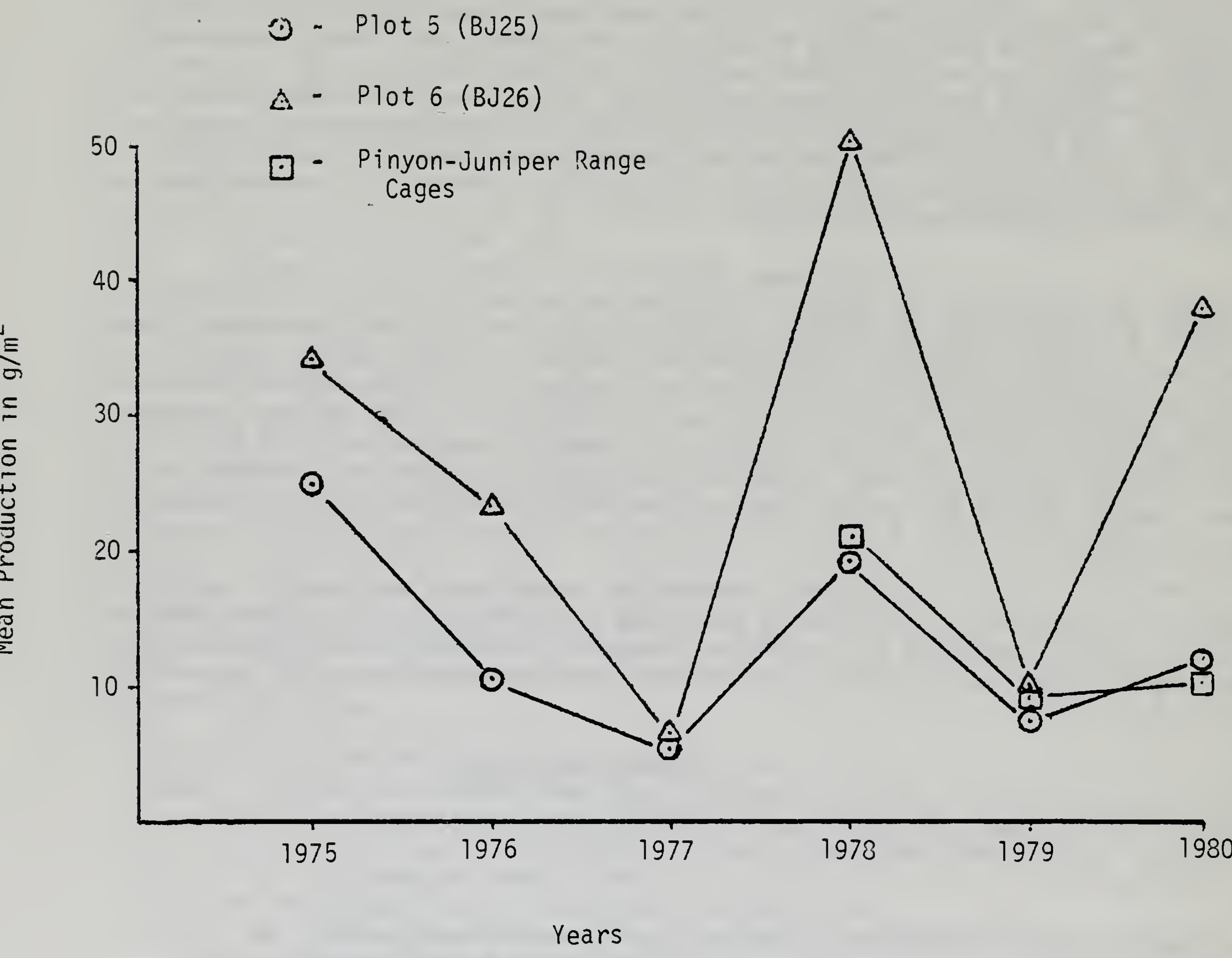


Figure 8.7.2-1 Trends in mean herb production between 1974 and 1980 for pinyon-juniper woodlands. See Table 8.7.2-1 for actual values and estimates of variability.

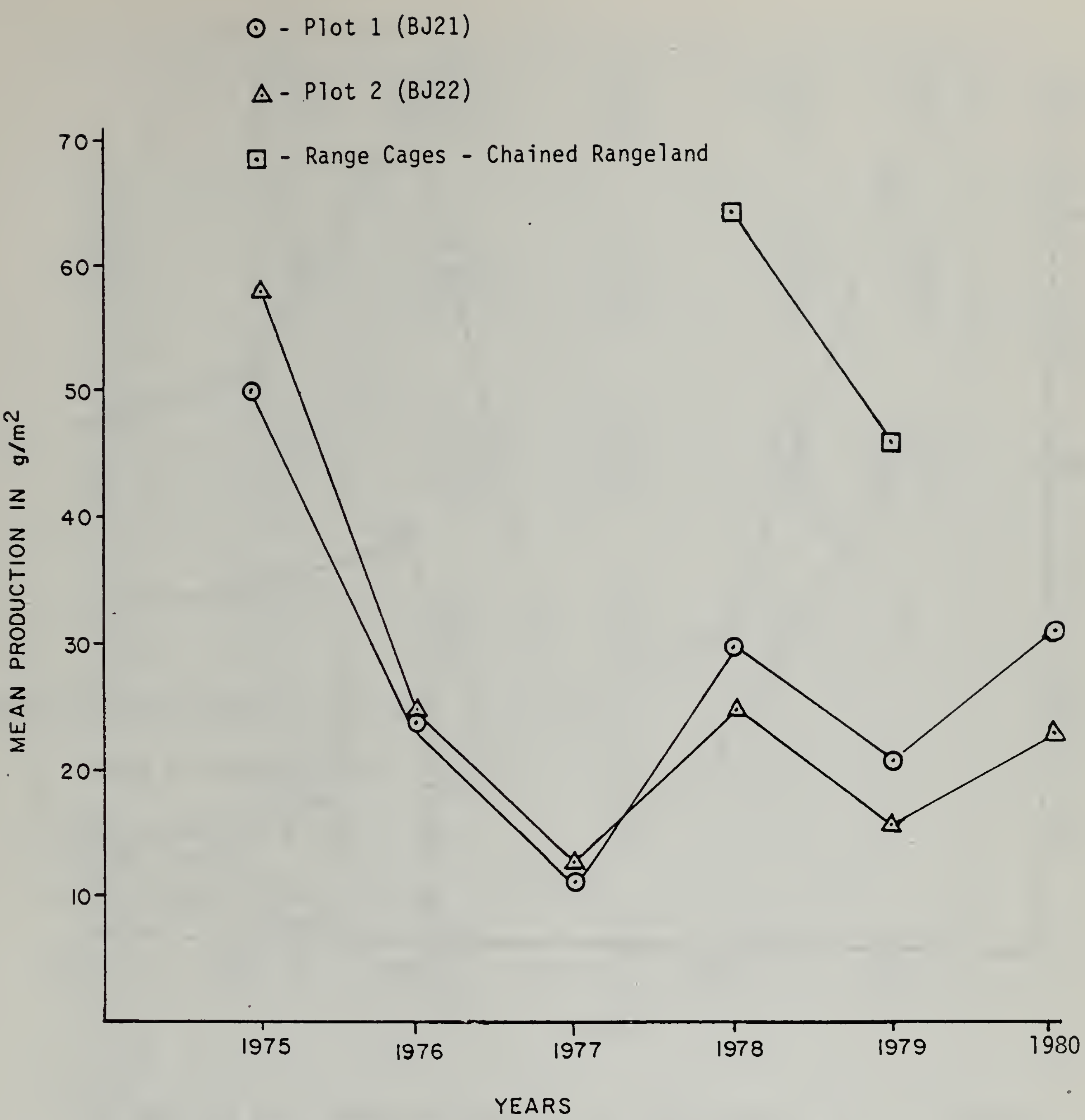


Figure 8.7.2-2 Trends in mean herb production between 1975 and 1980 for chained pinyon-juniper rangelands. See Table 8.7.2-1 for actual values and estimates of variability.

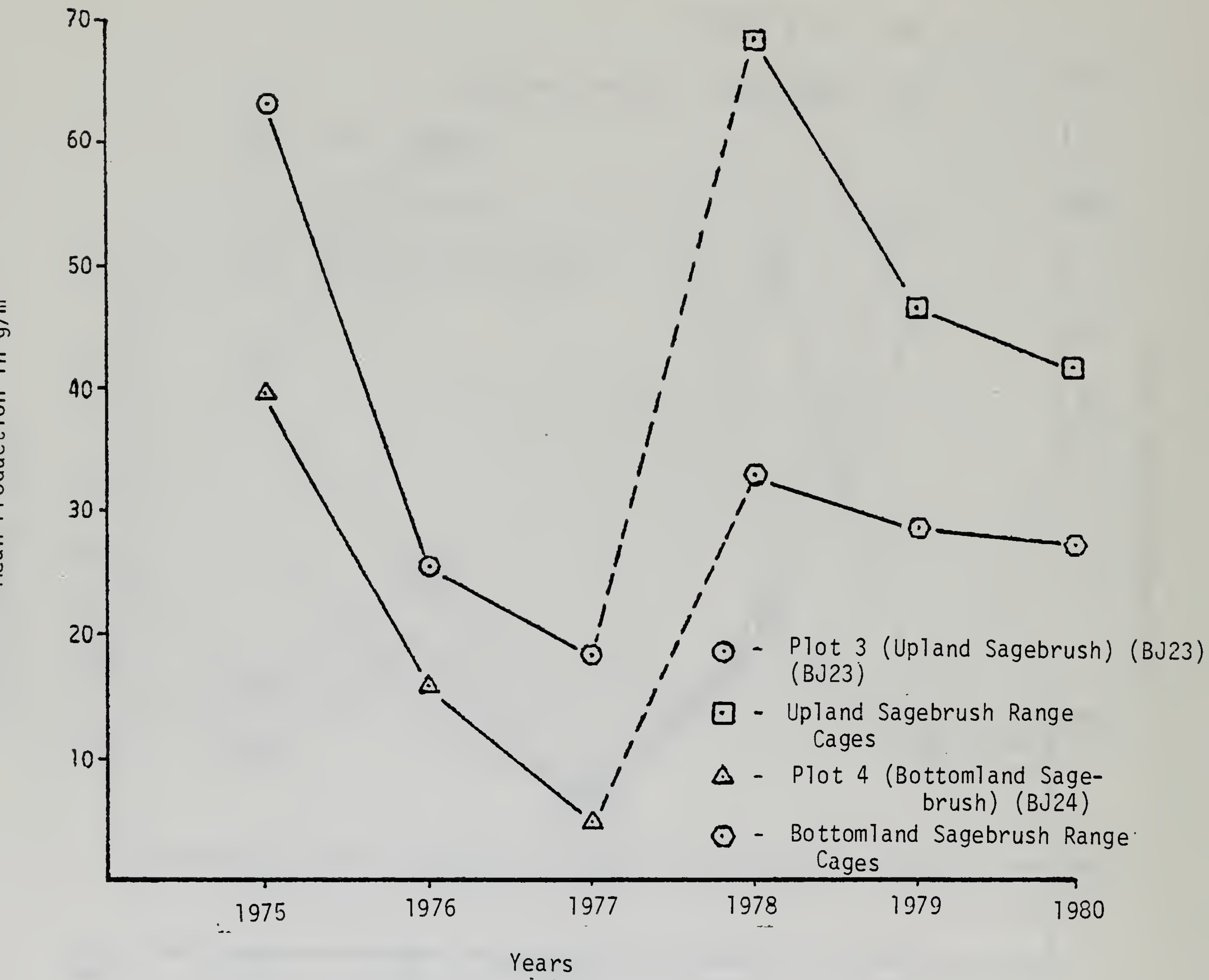


Figure 8.7.2-3 Trends in mean herb production between 1975 and 1980 for big sagebrush vegetation types. Data from 1975-1977 collected at intensive study Plots 3 and 4. Data from 1978-1980 collected from randomly located range cages in each of the types. The dotted line connecting the 1977 and 1978 data indicates the change in sampling approach for these two vegetation types. See Table 8.7.2-1 for actual values and estimates of variability.

TABLE 8.7.2-1

Mean Production (g/m^2) $\pm$ the Standard Error of the Mean for the Major Vegetation Types on Tract C-b for 1975-1980. No Range Cages Were Sampled Prior to 1978. Sagebrush Study Plots Have Not Been Sampled Since 1977. See Also Figures 8.7.2-1, 8.7.2-2 and 8.7.2-3

Vegetation Types	1975	1976	1977	1978	1979	1980
Pinyon-Juniper Woodlands						
Plot 5 (BJ25)	25.0±6.2	10.6±1.9	6.2±0.5	19.5±2.3	8.4±0.8	12.0±0.9
Plot 6 (BJ26)	34.2±7.6	23.4±4.0	6.4±0.5	50.3±3.3	10.7±1.0	37.7±2.9
Range Cages				21.4±6.7	10.3±2.0	10.4±1.7
Chained Pinyon-Juniper Rangelands						
Plot 1 (BJ21)	49.3±6.3	23.2±4.6	11.1±0.9	29.5±2.5	20.7±1.3	30.6±2.3
Plot 2 (BJ22)	57.8±18.6	24.4±5.6	12.5±1.2	24.4±1.7	15.4±1.7	21.8±1.6
Range Cages						
Upland Sagebrush Shrublands						
Plot 3 (BJ23)	63.0±6.8	25.5±3.1	18.2±0.6	N.S.	N.S.	N.S.
Range Cages				68.0±10.7	46.7±4.9	42.8±3.8
Bottomland Sgebrush Shrublands						
Plot 4 (BJ24)	39.6±9.0	15.4±3.1	4.5±0.7	N.S.	N.S.	N.S.
Range Cages				32.9±6.1	28.4±5.1	27.0±6.8

N.S. = Not Sampled

The production data for the four major vegetation types on the Tract is consistent with results obtained over the past five years. The upland sagebrush type was the most productive followed by the chained rangeland type, bottomland sagebrush type and pinyon-juniper woodland type.

Intensive Study Plots. Productive data were collected at Plots 1, 2, 5 and 6 (BJ21, BJ22, BJ25, and BJ26) during 1980. Plots 1 and 2 are in the chained rangeland type, and Plots 5 and 6 are in the pinyon-juniper woodland type. Fresh weight estimates for each of the quadrats are presented in Table A8.7.2-9 - A8.7.2-12, and oven dry weights for each of the ten clipped quadrats at each plot are presented in Table A8.7.2-13 - A8.7.2-16. The regression equations used to convert the fresh weight estimates to oven dry weights are presented in Tables A8.7.2-17 - A8.7.2-20.

In general the chained rangeland intensive study plots tend to be less productive than the chained rangeland type as a whole. Mean total production was 30.6 g/m^2 (273 lbs/acre) at Plot 1 and 21.8 g/m^2 (194 lbs/acre) at Plot 2. This compares with 40.8 g/m^2 for the range cages in the chained rangeland. The major species are the same with most of the production attributable to perennial grasses, western wheatgrass and Indian ricegrass (Table A8.7.2-21).

In the pinyon-juniper woodland plots, the same pattern observed during the last five growing seasons was repeated during 1980. Plot 6 was more productive that Plot 5 (Table A8.7.2-22). Mean total production was 37.7 g/m^2 (336 lbs/acre) at Plot 6 and 12.0 g/m^2 (107 lbs/acre) at Plot 5. Major species include perennial grasses, western wheatgrass, and Indian ricegrass. Compared with the pinyon-juniper woodland type as a whole, Plot 5 is more similar in terms of total production. Because of the denser understory at Plot 6, the production at that site is more similar to that measured in the upland sagebrush type.

Trends in Herbaceous Production 1975 - 1980. Trends in herbaceous production were reported in the 1979 monitoring report. The 1980 data have been included with the previous year's data. In pinyon-juniper woodlands and chained rangelands intensive study plots were more productive in 1980 than 1979 (Table 8.7.2-1 and Figures 8.7.2-1 and 8.7.2-2). The mean production for range cages in the chained rangelands was slightly lower in 1980 than it was in 1979. Both the upland and bottomland sagebrush types were also somewhat less productive in 1980 compared with 1979 (Table 8.7.2-1 and Figure 8.7.2-3). the reported values for 1980 are well within the ranges observed in previous years. Based on the responses of the paired pinyon-juniper plots and the paired chained rangeland plots, there are no apparent changes in production resulting from construction activities on the Tract. The patterns of production are consistent with those observed over the past five years.

Evaluation of Production Differences, 1980

Differences Among Vegetation Types and Study Sites. All of the differences in production among the intensive study plots wre significant (Table 8.7.2-2). The production of Plot 1 was significantly more productive than Plot 2, but significantly less productive than Plot 6. Plot 2 was

Table 8.7.2-2 One-way analysis of variance results for comparison in open and fenced plots and evaluation of differences among sites and vegetation types, 1980. Underlined items are those with the greater mean value.

	Calculated F	ν_1*	ν_2*	Critical Region $\alpha = 0.10$ F>	Significance*
DIFFERENCES IN UTILIZATION					
Range Cage Data					
Pinyon-Juniper Open vs. Pinyon Juniper Fenced	0.004	1	28	2.890	NS
Chained Rangeland Open vs. Chained Rangeland Fenced	2.003	1	28	2.890	NS
Upland Sagebrush Open vs. Upland Sagebrush Fenced	9.305	1	26	2.910	SIG
Bottomland Sagebrush Open vs. Bottomland Sagebrush Fenced	1.051	1	28	2.890	NS
Irrigated Chained Rangeland Open vs. Irrigated Chained Rangeland Fenced	0.329	1	18	3.010	NS
DIFFERENCES AMONG VEGETATION TYPES AND STUDY SITES					
Pinyon-Juniper and Chained Rangeland					
Plot 1F vs. Plot 2F	9.426	1	98	2.764	SIG
Plot 1F vs. Plot 5F	55.924	1	98	2.764	SIG
Plot 1F vs. Plot 6F	3.709	1	98	2.764	SIG
Plot 2F vs. Plot 5F	27.058	1	98	2.764	SIG
Plot 2F vs. Plot 6F	22.588	1	98	2.764	SIG
Plot 5F vs. Plot 6F	71.578	1	98	2.764	SIG
Based on Range Cage Data					
Pinyon Juniper vs. Chained Rangeland	62.101	1	28	2.890	SIG
Pinyon-Juniper vs. Upland Sagebrush	62.534	1	27	2.900	SIG

Table 8.7.2-2 (contd.) Comparison in open and fenced plots and evaluation of differences among sites and vegetation types, 1980.

	Calculated F	ν_1*	ν_2*	Critical Region $\alpha = 0.10$ F>	Significance*
Pinyon-Juniper vs. Bottomland Sagebrush	5.581	1	28	2.890	SIG
Chained Rangeland vs. Upland Sagebrush	0.153	1	27	2.900	NS
Chained Rangeland vs. Bottomland Sagebrush	3.220	1	28	2.890	SIG
Upland Sagebrush vs. Bottomland Sagebrush	3.892	1	27	2.900	SIG
Chained Rangeland vs. Irrigated Chained Rangeland	7.815	1	23	2.940	SIG
Based on Range Cage and Intensive Study Plot Data					
Plot 1 vs. Chained Rangeland Cages	4.858	1	63	2.789	SIG
Plot 2 vs. Chained Rangeland Cages	28.186	1	63	2.789	SIG
Plot 5 vs. Pinyon Juniper Cages	0.815	1	63	2.789	NS
Plot 6 vs. Pinyon Juniper Cages	25.607	1	62	2.789	SIG
Plot 6 vs. Upland Sagebrush Cages	0.755	1	63	2.789	NS

* NS = Not Significant
SIG = Significant
ν_1 = degress of freedom for numerator
ν_2 = degress of freedom for denominator

significantly more productive than Plot 5 but significantly less productive than Plot 6. Plot 6 was significantly more productive than Plot 5. Plot 6 had the highest production of any of the intensive study plots. The high production at this site is contrary to the pinyon-juniper type as a whole. There was no significant difference between Plot 5 (the other pinyon-juniper site) and the range cages in the pinyon-juniper woodlands. Plot 6 was significantly more productive than both Plot 5 and the pinyon-juniper range cages. The understory at Plot 6 is quite well developed and more closely resembles the upland sagebrush type. In fact, there was no significant difference between Plot 6 production and the production in the upland sagebrush range cages. In other comparisons between the intensive study plots and range cages, the chained rangelands as a whole were signficantly more productive than either Plot 1 or Plot 2 (Table 8.7.2-2).

The differences among the four major vegetation types are comparable to results obtained in previous years. On the basis of the range cage data, the pinyon-juniper woodlands were significantly less productive than the chained rangelands, uplands sagebrush and bottomland sagebrush shrublands. The chained rangelands and upland sagebrush shrublands were significantly more productive than the bottomland sagebrush shrublands. There was no significant difference between the chained rangelands and upland sagebrush shrublands.

Evaluation of Herbaceous Utilization. In all the range cage sampling except for the irrigated chained rangelands, the production in the range cages was greater than in the adjacent open areas. In the pinyon-juniper woodlands the values were nearly the same which is a reflection of both limited utilization and variability in herb layer production. In the upland sagebrush, utilization was measured at 33 percent; in the bottomland sagebrush, utilization was 34 percent; and in the chained rangeland, utilization was 18 percent. Of these, the only significant difference between caged and open areas was in the upland sagebrush shrublands (Table 8.7.2-2). These results are consistent with those reported in earlier years. The high percentage of perennial grasses, total production values, and open aspect of the upland sagebrush shrublands apparently make them more desirable for livestock use.

Irrigation/Fertilization Studies 1980. Fresh weight estimates for each of the ten sampled quadrats in the irrigation study plots are presented in Table A8.6.2-23 and dry weights for the clipped plots are presented in Table A8.7.2-24. The regression equations for converting the fresh weight estimates to oven dry weights are presented in Table A8.7.2-25.

In general at the time of sampling, the effects of fertilization and irrigation were very limited. Mean values for each of the fertilizer treatments ranged from 36.3 to 47.0 g/m^2 (Table A8.7.2-26) which is comparable to that measured for chained rangelands as whole (40.8 g/m^2). The highest production estimate (63.7 g/m^2) in this study came from the non-fertilized plot which was irrigated for 12 hours. Data for this treatment came from ten clipped plots adjacent to range cages rather than from a double sampling approach (Table A8.7.2-27 and A8.7.2-28). The third highest value (46.7 g/m^2) came from the other non-fertilized plot.

Evaluation of the effects of fertilizer and irrigation were evaluated using a two-way analysis of variance. Fertilizer effects, irrigation effects and the interaction of fertilizer and irrigation were each tested (Table 8.7.2-3). Irrigation effects and interaction effects were not significant, however the fertilizer effects were significant. The highest mean value among the as 18 fertilizer treatments was the "no fertilizer" block.

Two factors stand out as important in the evaluation of the fertilization/irrigation data. The site had been irrigated only twice prior to clipping in late July. There was not enough time for the treatments to take effect and actually be manifested as increased production. Clipping later in the year, possibly as late as early September, would likely increase the chance of detecting treatment effects. The second factor masking the treatment effects is the variability of herb production in the chained rangeland. The production in the no-fertilizer 12 hour irrigation was the highest measured in the chained rangelands during 1980. In fact both the cages and open areas were significantly greater than the production in the chained rangelands as a whole. The high values for this treatment were primarily responsible for the significance of the fertilizer treatment effects.

8.7.2.6 Conclusions

The conclusions reached in this report are essentially the same as those reached in previous years monitoring studies.

1. The patterns of production are essentially the same as those observed during the baseline and previous monitoring years.
2. In 1980 herbaceous utilization of non-woodland vegetation types was 28 percent. The only type where the difference between range cages and open areas was significant was the upland sagebrush shrubland type. This result is the same as that obtained in 1979.
3. Differences in production at Plots 1, 2, 5, and 6 were statistically significant. These differences most likely relate to natural causes rather than to development activities.
4. The fertilization/irrigation program results showed significant fertilizer effects and non-significant effects for irrigation and irrigation-fertilization interaction. The results of the program are somewhat masked by the variability of the chained rangeland type and the initial short duration of the fertilization/irrigation program.
5. Visual observations of the irrigation/fertilizer study area made in late August and September support the statement made earlier that clipping later in the year would likely increase the chance of detecting treatment effects. It was evident from these observations that vegetative production in irrigated areas was greater than surrounding non-irrigated areas. This difference in production was even more apparent in the fertilized blocks, particularly for the 200/100 application rate (Treatments 4a and 4b). At the time of data collection in 1980 it was not realized that the sprinkler irrigation would produce the effect of a prolonged growing season (vegetation was still green and growing into September) on the vegetation at the C-b Tract.

Table 8.7.2-3 Results of the two-way analysis of variance test for evaluating the effects of fertilization and irrigation.

Source of Variation	Degress of Freedom	Sum of Squares	Mean Square	Calculated F	Significance*
Subgroups	7	4509.59	644.23		
A (Columns; fertilizer)	3	2997.42	999.14	5.281	SIG
B (Row; irrigation)	1	526.96	526.96	2.785	NS
AxB (Interaction)	3	985.21	328.40	1.736	NS
Within Subgroups (Error)	72	13620.97	189.18		
Total	79	18130.56			

$F_{0.05\,[3,79]} = 2.733$ $F_{0.05\,[1,79]} = 3.976$

* SIG = Significant at $\alpha = 0.05$
NS = Not significant at $\alpha = 0.05$

8.7.3 Shrub Productivity and Utilization

This section has been incorporated into Section 8.2.2 entitled Browse Production and Utilization in this report.

8.7.4 General Vegetation Conditions Study

This section has been incorporated into this Section 4.2 utilizing Landsat.

8.7.5 Micro-Climatic Studies

8.7.5.1 Scope

Studies on microclimatic parameters on the C-b Tract provide data that are useful in assessing changes in vegetation production and structure, animal populations, or animal activity patterns, and may also be correlated with changes in functional components of the C.B. ecosystem that may occur as a result of oil shale development.

8.7.5.2 Objectives

The objectives are to measure and evaluate time trends in climatic variables of surface and air temperatures, surface precipitation, and snow depth at specific locations within the various vegetative communities; to provide data for ecosystem interrelationship studies.

8.7.5.3 Experimental Design

Five microclimatic stations are located in development sites and five in control sites. The locations of these ten sites (See Stations BC01 through BC09 and BC13 on the jacket map, Exhibit C) are the same as baseline locations. Therefore, data from March 1975 through the present can be compared. Each station is monitored twice monthly for the following parameters:

Microclimate Station Locations		Parameters Measured at each Station
BC01	Chained Pinyon-Juniper Rangeland	Air Temperature: 1m
BC02	Chained Pinyon-Juniper Rangeland, Vegetation Plot 2	Soil Temperature: Surface
BC03	Plateau Sagebrush, Vegetation Plot 3	Precipitation, Snow Depth and Moisture Content
BC04	Valley Bottom Sagebrush, Vegetation Plot 4	
BC05	Pinyon-Juniper Woodland, Vegetation Plot 5	
BC06	Pinyon-Juniper Woodland, Vegetation Plot 5	
BC07	Chained Pinyon-Juniper Rangeland (Animal Trapping Transect)	
BC08	Bunchgrass Community, South-facing Slope	
BC09	Valley Bottom Sagebrush, Mouth of Sorghum Gulch	
BC13	Mixed Mountain Shrubland, North-facing Slope	

All temperature readings consist of maximum and minimum readings for two-week periods. Precipitation is measured only during the growing season, March through October. Therefore, precipitation data from meteorology stations AB20 and AB23 are utilized for winter-month readings (November-February) for valley and pinyon-juniper microclimate stations. Snow measurements are obtained approximately from November-February.

8.7.5.4 Method of Analysis

Methods of analysis include time series plots contained in the Supplement(s) to the Development Monitoring (data) Reports for precipitation, snow depth, and maximum and minimum temperatures, and correlations of microclimatic data with plant and wildlife data. The reader should also consult Subsection 6.3.1, Climatological Records, for additional tables, time series plots, and histograms.

8.7.5.5 Discussion and Results

Time series plots for 1980 (see Jan. 1981 Data Report) were visually compared to time series plots from previous years. Observations resulting from this analysis are:

Fall and Winter precipitation values were lower, but Spring and Summer precipitation values were similar to previous years.

Temperatures dropped below freezing for short periods throughout the growing season, but were similar to past years.

Temperatures for January, thru March were lower than in previous years.

8.7.5.6 Conclusions

The following conclusions were drawn from the visual analysis:

a. Winter and Fall precipitation for 1980 was lower than previous years.
b. Spring and Summer precipitation for 1980 was similar to previous years.
c. Below freezing temperatures during the growing season were noted but were similar to previous years.
d. Lower temperatures were recorded for January thru March than in previous years.

8.8 Threatened and Endangered Species

Bald eagles were observed several times on Tract C-b and in the general vicinity. The raptors were not seen in any present or future developmental areas. No bald eagles nested or remained on the Tract for any great length of time. Since the area is not suitable for bald eagle habitat (marginal winter range) and the eagles were only occasional visitors, no further action will be taken except for their continued monitoring.

Sandhill cranes were observed several times east of the Tract. The birds were seen along Piceance Creek and up West Stewart Creek. No sandhill cranes were observed on the Tract. At this time, no further actions will be initiated with the exception of continued monitoring for their presence.

No threatened or endangered plants were found on or near Tract C-b. New plants are continually being added to the permanent herbarium on Tract.

In conjunction with the numerous biological studies that will be conducted on and near Tract C-b during all parts of the year, observations confirmed by staff field biologists of any threatened or endangered species will be reported to the OSO (Oil Shale Office). Appropriate studies to determine significance of a sighting will then be initiated as determined jointly by C.B. and OSO personnel.

8.9 Revegetation

Revegetation monitoring is conducted on sites which have undergone surface disturbance on topsoil storage piles and on shale disposal sites. Sampling of revegetated areas is initiated during the third growing season following seeding with a permanent seed mixture. Monitoring is conducted on areas larger that one acre. Monitoring techniques assess the progress of reestablished vegetation through determination of cover and productivity of species. Parameters to be studied on revegetated sites include species frequency and cover for forbs, grasses, and shrub and tree seedlings; cover by litter, soil, rock, mosses and lichens, and herbaceous standing crop.

8.9.1 Vegetation Structure and Composition

8.9.1.1 Scope

Sampling of revegetated areas during 1980 was done on the two topsoil storage piles located near the support facilities which were seeded in 1978. Sampling was accomplished in late July. Sampling included determination of herbaceous species frequency; percent cover by herbaceous species; and percent cover by litter, soil, rock, mosses, and lichens. Shrub and tree seedlings were not established enough to sample separately and were included in the herbaceous sampling.

8.9.1.2 Objectives

Vegetation structure and composition on revegetated disturbed sites are monitored in order to evaluate the general success obtained in re-establishing vegetation on these sites.

8.9.1.3 Experimental Design

Sampling for species frequency and percent cover was accomplished through the use of the quadrat-ocular-estimation method. A starting point was randomly located on each topsoil pile. A grid of 1.0 m^2 quadrats was then established. A total of 25 quadrats was sampled (13 on one pile

and 12 on the other were combined into one set of 25 data points). Observations on the herb and ground-layer components were made in the 1.0 m^2 quadrats.

The parameters being monitored in this study are cover and frequency for herbaceous species (including shrub and tree seedlings).

8.9.1.4 Method of Analysis

Percent cover by species, litter, soil, rock, mosses, and lichens was determined. Since there are no control sites for comparison with revegetated areas, no hypothesis will be tested nor will similarity indices be used. Also, since this is the first year's set of data for the revegetated topsoil piles, data cannot be evaluated through the use of trend analysis. The parameters that will be compared in this analysis are total herbaceous cover and frequency and percent cover of weedy annuals vs. the desired perennial grasses and forbs used in the seed mixture.

8.9.1.5 Discussion and Results

There are two sources of possible error involved in monitoring vegetation community structure and composition. First, in visual evaluation of species cover it is very difficult to be totally consistent from year to year and even from quadrat to quadrat, even if the data are recorded by the same observer. Second, difficulties in species recognition constitute a source of error which is difficult to eliminate. This are especially true for species in vegetative condition. Species recognition is manifested in both cover and frequency data. Visual estimates affect only the cover data.

The most prevalent species found on the topsoil piles include Russian thistle (Salsola iberica), intermediate wheatgrass (Agropyron intermedium), pubescent wheatgrass (A. pubesens), and western wheatgrass (A. smithii), respectively. These species had a frequency of 60 percent or greater. The species having greatest amounts of ground cover include Russian thistle, intermediate wheatgrass, alfalfa (Medicago sativa) and pubescent wheatgrass, respectively. These species had a mean cover of 2.4 percent or greater. Total mean cover in the herb layer was 25 percent. Bare soil had a mean cover value of 62.2 percent. Mean number of species per square meter was 6.12 $\pm$ 0.27.

The desired perennial grasses and forbs planted as seed had a combined mean cover of 15.9 percent compared to a combined mean cover of 12.4 percent for weedy annuals (most of which is attributed to Russian thistle's 11.1 percent mean cover). With the exception of Russian thistle (100% frequency), the desired species have a higher frequency than the weedy annuals.

All but four species of the seeded mixture were observed in the sampled quadrats. These four were mountain brome (Bromus marginatus), Great Basin wildrye (Elymus cinereus), hard fescue (Festuca ovina) and penstemon (Penstemon spp.). Four species of shrub seedlings were observed (five total seedlings) and six species of weedy annuals.

The herb quadrat summaries for the topsoil pile are shown in Table A8.9.1-1 of Volume 2A of this Annual Report.

8.9.1.6 Conclusions

Since this is the first year's data on revegetated areas it is difficult to draw any specific conclusions. It can be noted that the revegetated topsoil piles are definitely in a successional stage, which is to be expected. This fact is supported by the relatively low species diversity, as compared to the major vegetation types on tract and by the dominance of the weedy annual Russian thistle.

Past revegetation experience at C-b Tract at old drill pad sites has shown that weedy annuals such as Russian thistle tend to dominate the revegetated sites the first two growing seasons with the seeded perennial grass and forb species taking over dominance in the third and subsequent years. Therefore, next year's data (third growing season) are expected to show an increase in dominance of those species included in the seed mix used. We should then be able to state whether or not the revegetated topsoil piles are advancing towards a desired plant community or it is in a state of regression.

8.9.2 Productivity

8.9.2.1 Scope

Sampling was done on the two topsoil piles described in the previous sections. The parameter being sampled is herbaceous productivity. Sampling included determination of the productiveness of individual species as well as the site as a whole.

8.9.2.2 Objectives

Herbaceous standing crop on revegetated sites is measured in order to determine successive changes in this parameter over time and to evaluate the productivity of these sites.

8.9.2.3 Experimental Design

A double sampling technique was used to determine production. Twenty-five 1.0 m^2 quadrats were sampled. Quadrats from both topsoil piles were again combined to make a total of 25 data points (13 quadrats from one pile and 12 from the other). At the time of estimated peak standing crop, an ocular estimate of the current year's growth of each species for each quadrat was made. Additionally, five of the quadrats were clipped and individual species were bagged separately. The clipped species were returned to the lab, oven-dried to a constant weight and weighed to the nearest 0.01 gram. A regression equation for ocular estimates to oven dry weights was determined and the ocular estimates were adjusted accordingly.

8.9.2.4 Method of Analysis

Yearly production of weedy annual species vs. desired perennial species is compared, as well as the productiveness of the revegetated site as a whole vs. the productiveness of the major vegetation types on Tract.

No hypotheses testing for significant differences will be done, due to the lack of a comparable control site and successional changes expected.

8.9.2.5 Discussion and Results

Fresh weight estimates for each of the 25 quadrats sampled are presented in Table A8.9.2-1. Oven dry weight data for the five clipped quadrats are presented in Table A8.9.2-2. Regression equations (Table A8.9.2-3) were developed for each individual species to convert fresh weight estimates (x) to oven dry weight estimates (y) based on the quadrats which were both estimated and clipped.

Mean total production of the topsoil piles was 86.9 g/m^2 (775 lbs./acre). Most of the production is attributable to intermediate wheatgrass, Russian thistle and pubescent wheatgrass (Table A8.9.2-4).

The desired perennial grasses and forbs had a combined mean production of 58.6 g/m^2 (523 lbs./acre) compared to a combined mean production of 28.3 g/m^2 (252 lbs./acre) for the weedy annuals.

Mean total production of range cages is used here for comparison of the revegetated area vs. the productiveness of the major vegetation types on the Tract. Mean total production of the chained pinyon-juniper rangelands was 40.7 g/m^2 (363 lbs./acre). Mean total production of the pinyon-juniper woodland was 10.4 g/m^2 (93 lbs./acre). Mean total production of the upland sagebrush community type was 42.7 g/m^2 (381 lbs./acre). Mean total production of the bottomland sagebrush community was 27 g/m^2 (241 lbs./acre). These mean total productions compare with the mean total production of 86.9 g/m^2 (775 lbs./acre) of the revegetated area. As can be seen, the revegetated area is a little more than twice as productive as the most productive vegetation-type on tract. Even with the mean production of the weedy annuals (28.27 g/m^2) subtracted from the total mean production (net result of 58.59 g/m^2, or 523 lbs./acre), the revegetated area is still more productive than the major vegetation types.

8.9.2.6 Conclusions

There are two conclusions which can be made from the first year's data of the revegetated topsoil piles. (1) The production of the perennial species is greater than that of the annual species (approximately 48% greater). (2) The production of the revegetated area is greater than that of the major vegetation types on tract.

8.9.3 Demonstration Plot

No demonstration plot for revegetation has been constructed. Demonstration plots of limited scale are expected to be constructed during 1981 for both processed and raw shale. The appropriate OSO personnel will be notified of demonstration plot specifics prior to construction.

8.10 Systems Dependent Monitoring

Additional aquatic studies, sublethal biochemical studies, and soil plant elemental analysis, are potential system dependent monitoring programs. They were not "triggered" by indicator variables, and therefore no monitoring for them was accomplished during 1980. However, additional monitoring in areas of the land application (sprinkler) system is systems dependent and is discussed in Sections 8.7.1, 8.7.2 and 8.11.2.

8.11 Special Projects

The main purposes of these special projects are to mitigate effects that oil shale development may have on fish and wildlife and/or to fulfill Lease requirements. These projects will be continued on a yearly basis depending upon the successfulness and usefulness of each individual project.

8.11.1 Brush Beating Project

Two sagebrush gulches (Gardenhire and Oldland) were brush beaten as a mitigation project to: (1) improve forage for wildlife and livestock, (2) reduce deer winter range use by livestock, and (3) reduce the deer roadkill. The beating was conducted to provide more forage for deer in areas were it was lacking. In addition, catch basins were built to collect spring runoff and possibly reduce the number of deer crossing the highway for water.

The mature sagebrush stands were knocked down by a D-8 Caterpillar equipped with an 8000 pound brush beater. The mature sagebrush was killed and the areas were reseeded. Table 8.11.1-1 shows the work done in these gulches. The areas were seeded with broadcast seeders using a mixture of early spring grasses, forbes and browse species. The application rate was approximately 18 lbs/acre. Table 8.11.1-2 gives the species mixture applied. Both developmental and control transects for deer-pellet group density and lagomorph abundance were established to evaluate use in the areas. Sampling was also done for vegetation species and composition.

Vegetation sampling consisted of sampling herbaceous species and shrubs, with the exception of sagebrush (Artemisia tridentata), for species frequency and annual production. Sampling was done along randomly located transect lines, one each in both gulches where brush beating occurred and one control transect (no brush beating). Each transect consisted of sampling 25 one-square-meter quadrats.

Frequency was determined for individual species encountered at each site. Mean annual production was determined for individual species as well as entire sites. Production was determined using a double sampling approach described in Section 8.7.2.3. The data and results are listed in Tables A8.11.1-1 through A8.11.1-10 of the Appendix.

More species were encountered in the two brush beating sites than in the control site. There were 17 different species in Oldland Gulch, 16 in Gardenhire Gulch and 11 in the control site. Mean herbaceous production for the entire brush beating sites was approximately twice as productive as that for

TABLE 8.11.1-1

Brush Beating

Area	Gardenhire Gulch 51 Acres	Oldland Gulch 51 Acres
Sagebrush	Mature sagebrush up to 7' tall	Mature sagebrush up to 10' tall
brush beat	Late winter 79-80	Early winter 79-80
seeded	After brush beating	Before brush beating
harrowed	Yes	No
Cattle use	Rest Rotation - 1980	Rest Rotation - 1980
catch basin	One	One
*Transects	Two deer pellet group density and Lagomorph abundance transects	Two ...... Transects
Photo Points	Two	Two

* Three control transects were established in adjacent draws.

TABLE 8.11.1-2

Sagebursh Mitigation
Species Mixture for Planting in the Big Sagebrush Type

	SPECIES		LBS/ACRE DRILLED	LBS/ACRE BROADCAST
Grasses:	* Agropyron cristatum	- crested wheatgrass	2	3
	* A. smithii (rosana)	- western wheatgrass	1	2
	* A. intermedium (amur)	- intermediate wheat-grass	1	1
	* Elymus cinereus	- Great Basin wildrye	1	2
	* E. junceus	- Russian wildrye	3	4
Forbs:	* Medicago sativa	- Alfalfa	1/2	1/2
	* Melilotus officinalis	- yellow sweet clover	1/2	1/2
	* Atriplex canescens	- four wing saltbrush	2	3
	* Eurotia lanata	- winterfat	1	1
	* Purshia tridentata	- bitterbrush	1/2	1/2
		TOTAL	12	18
			LBS/ACRE	

* Seed (P.L.S. - Pure Live Seed)

the control site. Mean annual herbaceous production in Oldland Gulch was 37.2 g/m^2 (322 lbs/acre), in Gardenhire Gulch production was 36.07 g/m^2 (158 lbs. acre).

Results indicate that opening the canopy cover of sagebrush through the use of a brush beater increases species abundance and herbaceous species production.

8.11.2 Raw Shale Lysimeter Tests

The raw shale lysimeters were constructed to fulfill Lease requirements to ensure that degradation of the environment with contaminated runoff water from the shale piles does not occur.

Three raw shale lysimeters were constructed in November and December 1980. Each of the lysimeters has a collecting surface area measuring 10' x 10'. The three collectors were covered with raw shale mined from the Intermediate Void Level of the Production Shaft and the Upper Voil Level of the Ventilation/Escape Shaft to depths to 10, 15, and 20 feet, respectively. The three collectors are constructed entirely of teflon components to minimize contamination (see Figure 8.11.2-1).

No leachate data were collected from the lysimeters during 1980. The leachates will come from precipitation that percolates through the raw shale to the collectors. The following is a list of parameters for analysis in the leachates from the raw shale lysimeters:

- Comprehensive Analysis on Selected Samples - Aluminum, Ammonia, Arsenic, Asbestos, Barium, Beryllium, Bicarbonate, Boron, Cadium, Calcium, Carbonate, Chloride, Chromium, Cobalt, Copper, Cyanide, Flouride, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Nitrate, Total Nitrogen, Phosphate, Total Phosphorus, Potassium, Selenium, Silica, Silver, Sodium, Strontium, Sulfate, Sulfide, Thallium, Thiosulfate, Tin, Titanium, Uranium, Vanadium, and Zinc.

  Alkalinity, Conductivity, pH, TDS, DO, and Temperature, Organic Fractionization.

- Routine Analysis for Each Sample - Aluminum, Bicarbonate, Boron, Calcium, Carbonate, Chloride, Flouride, Magnesium, Molybdenum, Potassium, Selenium, Silica, Sodium, Sulfate, Thiosulfate, and Zinc.

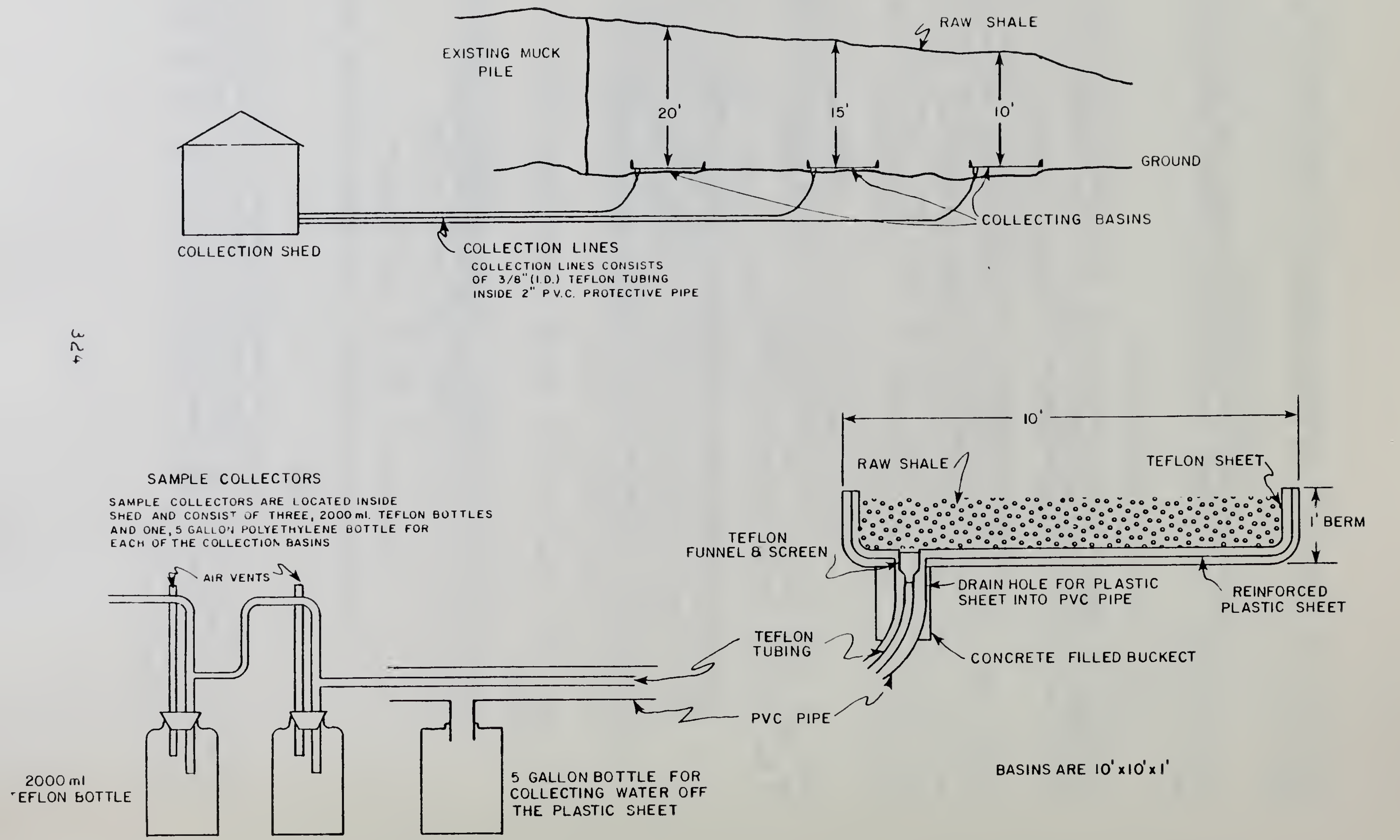
  Alkalinity, Conductivity, pH, TDS, DO, and Temperature.

8.11.3 Excess Mine Water Disposal - Land Application System Impacts

8.11.3.1 Scope

Excess mine water was disposed on approximately 100 acres using large sprinklers starting in mid-July and ending in mid-Ocotober. Sprinkling is limited to spring, summer and fall months during the time when atmospheric and vegetative water demands are relatively high. During this period, water can be safely applied by sprinkling with a limited risk of disrupting the environmental balance.

FIGURE 8.11.2-1 RAW SHALE LEACHATE STUDY SITE



The principal mechanisms of water disposal to the air are evaporation, from the time water leaves the nozzle until the soil and plant surfaces are dry, and transpiration when the leaf stomata are open. Evaporation and transpiration should balance (consume) the amount of water applied to the soil by precipitation and sprinkling to limit water percolating below the root zone. This limits leaching of salts from the soil thus preserving groundwater quantity and quality.

Salt in the applied water is concentrated in the soil by evapotranspiration when leaching is avoided. Plants will benefit from the irrigation as long as the salinity of the soil and specific ion concentrations do not reach toxic levels.

Potential hazards associated with salts in the irrigation water when applied by sprinkler are their accumulation in and on vegetation. High levels of specific ions in the foliage can effect the plant and animals that consume large quantities of the vegetation. Some plants are sensitive to sodium and boron while flouride can harm animals.

8.11.3.2 Objective

The purpose of this study is to monitor the environment and to control the irrigation application such that the maximum amount of excess mine water can be safely disposed via the evapotranspiration processes without significant deep percolation.

The system is managed so that deep percolation is limited, toxic soil salt levels are avoided, and salts accumulated on or in the plant foliage will not damage plants or the animals that consume it. Using the results of the study to date, recommendations are made for operating the system in the future and for continuing the monitoring program.

8.11.3.3 Experimental Design

The sprinkler system was only operated during the latter part of the 1980 season. Thus the monitoring procedures, sprinkler equipment and field procedures were only tested for a relatively short period of time. Treatments designed for the study are presented in Table 8.11.3-1. Figure A8.11.3-1 shows a sketch of the irrigation system layout including the locations of the sample (treatment) sites.

Water Distribution System

Water was pumped from Pond C to and through the mainline which is buried on the ridge top. Sprinkler laterals were placed at approximately right angles to the main (see Figure A8.11.3-1). Quick-coupled big-gun sprinklers were attached to risers on stands along the laterals. The system was designed to deliver 220 gallons per minute (gpm) to each of two operating sprinklers for a total of 440 gpm. Rainbird Model 105CS sprinklers with 0.89 inch straight bore nozzles discharged the water over a circular area having a wetted radius of approximately 160 feet. The average application rate, using

TABLE 8.11.3-1

Treatments and Items Measured During the Impact Study of Excess Mine Water Disposal by Irrigation During the 1980 Season.

Treatment	Set Time Hours	Set Period 1/	Irrigation Interval days2/	Number of Samples and Items Monitored 3/
4a4/	18	Random	15	10P5/, 4W
4b	12	Random	15	10P, 4W
5a	18	Random	15	10P, 3, 4W
5b	12	Random	15	10P, 10B, 10F, S, 10W, 5Na
5c	6	Random	15	S, 4W
6b	12	Day	15	5B, 5F, 5Na
7c	6	Day	76/	5B, 5F, S, 4W, 5Na
8b	12	Night	15	5B, 5F, 5Na
C	--	--	--	4W

1/ Period of time when irrigated

2/ Actual intervals used varied considerably (see irrigation data in Table 8.11.4-3).

3/ Letters represent the following:

P - Herbaceous productivity
S - Soil Sample
W - Soil Water
B - Plant boron
F - Plant flouride
Na - Plant Sodium

4/ Treatments 4a and 4b received application of 200 lbs N and 100 lbs P per acre.

5/ Herbaceous productivity determined by Cathedral Bluffs Oil Shale Co.

6/ Two irrigations per 15 day interval.

the flow rate and wetted area, was 0.67 centimeters per hour (cm/hr) or 8.0 cm per 12 hours. The standard operating time was 12 hours per set except in the study area. Various application amounts were applied in the intensively monitored study areas. The different amounts were achieved by using application times of 6, 12, and 18 hours, giving 4.0 cm, 8.0 cm and 12.0 cm application amounts (Table 8.11.3-1).

8.11.3.4 Methods of Analysis

Soil Water

Drainage (deep percolation) below the root zone can be estimated from the water applied at a given point and changes in soil moisture as a function of time and depth. However, this was not done in the 1980 season because of lack of data. Deep percolation can also be estimated from a water budget using a method of calculating comsumptive water use from meteorologic data which was available at the site.

Water content was initially measured by the gravimetric technique (mass basis) and later by using a Campbell Pacific Hydroprobe neutron moisture meter (see data in Table A8.11.3-2). An Oakfield soil sampler was used to extract samples for measuring soil moisture on a mass basis. To convert these to a volume basis, which was necessary for comparison with the Hydroprobe readings, they were multiplied by the bulk density of the soil which was approximately 1.1 grams per centimeter cubed (g/cm^3). Thus, the gravimetric and volumetric water contents were nearly the same.

The Hydroprobe was not delivered until late in the season and was only used to take the final moisture readings. Access tubes for the Hydroprobe were installed to the full soil depth in appropriate treatments to allow more convenient measurement of soil moisture before and after each irrigation. If the volumetric soil moisture at the lower depths is above field capacity (=32%) after an irrigation, it can be assumed that deep percolation is likely and the amount of irrigation should be reduced or the interval between irrigation increased. Use of the Hydroprobe will facilitate rapid and accurate moisture readings to use in irrigation management in future seasons.

Soil Water Quality

Excess mine water was sampled periodically and analyzed. Boron, total dissolved solids (TDS), and fluoride levels are presented in Table A8.11.3-3.

Soil salt movement and accumulation were estimated from the pH, electrical conductivity of saturation extracts (ECe), exchangeable sodium percentage (ESP), and boron concentration (see data in Table A8.11.3-4). Samples were taken with an engine powered soil auger on June 5 in conjunction with the installation of the Hydroprobe access tubes. On December 16, an Oakfield soil auger was used to extract the soil samples at the same locations.

Foliar Salts

Indian ricegrass (Oryzopsis hymenoides), western wheatgrass (Agropyron smithii), and big sagebrush (Artemesia tridentata wyomingenses or Artemesia tridentata tridentata) were caged and in each case new growth was sampled (see data in Tables A8.11.3-5 - A8.11.3-7). Samples were taken on June 5 and December 16 from the same plants or an adjacent area. In treatment areas where both soil moisture and foliage were sampled the plant samples were taken from plants near the access tubes.

8.11.3.5 Results and Discussion

Deep Percolation and Lateral Seepage.

Water budgeting was used to estimate deep percolation by accounting for daily consumptive use and estimating the available soil water storage for use by the plants. The process begins by assuming no stored water is available. Following the first and subsequent irrigations, water is consumed at a rate proportional to atmospheric water demand. The estimated amount of water used each day is subtracted from the stored water. Irrigation and precipitation replace the depleted water. When more water was added than the soil could store, deep percolation was assumed.

Estimates of daily consumptive water use, ET, and available water storage are used in the water budgeting process. The Hargreaves equation (1977) was used to estimate potential daily evapotranspiration (ETP) using weather data presented in Table A8.11.3-8. A five percent loss from drift and direct evaporation from spray was assumed (EFF = 95%). The weighted average crop cover, C = 0.70, was estimated by assuming an average irrigation interval of 21 days with full ET for the first 2 days following each irrigation and an average crop cover (density) of 2/3. Crop canopy architecture was assumed to be similar to alfalfa so K = 1.2 was used as the crop coefficient to give the following equation for predicting daily ET:

$$ET = \frac{CK}{EFF/100}\ ETP$$

$$= \frac{0.70 \times 1.2}{.95}\ (0.0075\ (1.8\ T + 32)\ RS)/(595.9 - 0.55\ T)$$

where

ET = consumptive use or evapotranspiration in cm/day
T = average daily temperature in °C
RS = the solar radiation in Langleys/day.

Both radiation and temperature data were recorded at the C-b tract, however, the radiation data received from C.B. for 1980 appeared to be in error when compared to past years' data from the C-b Tract and 1980 radiation data collected at Grand Junction. The C-b radiometer gave an average of 336 Langleys/day for July 1980 versus 633 at Grand Junction. Past years' daily average at the C-b Tract for July are: 538 Langleys in 1975, 558 Langleys in 1976, 520 Langleys in 1977 and 567 Langleys in 1979. Therefore, the C-b Tract solar radiation data was discarded and the Grand Junction data were used

to approximate RS. This appears to be a reasonable procedure in view of the proximity of the two locations, surrounding topography and the fact that Grand Junction data are more comparable to past years' data collected at C-b Tract than the 1980 C-b Tract data. C-b data errors were recently corrected, however, not in time for this annual report.

The following relationship for estimating solar radiation (RS) based on Hargreaves (1981) was used (in the general equation) for estimating daily ET:

$$RS = b\ (RA \times (\Delta T)^{1/2})$$

where

b is a coefficient which varies with location

RA is the extraterrestrial radiation in Langleys/day

ΔT is the difference between the maximum and minimum daily temperature in °F

The average July 1980 value of RS = 633 Langleys/day at Grand Junction (Table A8.11.3-9); RA = 1000 calculated from Christiansen (1968); and the average daily ΔT = 21.7 °F during July 1980 at the C-b Tract were used to compute b = 0.136.

Available water storage capacity was calculated from the Hydroprobe neutron moisture readings taken October 17 (Table 8.11.3-2). The unirrigated control treatment values were used to calculate the lower limit of available water (12.5%) and treatment 5a was selected for the upper limit (32%) since it was the last to be irrigated. The difference between these values was then multiplied by an average soil depth of 61 cm to arrive at 12 cm of available water storage for use by the plants. This is assumed to be the maximum amount of water which can be safely stored without deep percolation.

Estimated quantities of deep percolation calculated by the water budget method are presented in Table 8.11.3-3. A range of application times from 6 to 18 hours giving 4 to 12 cm of average application per irrigation was tested. Under the given irrigation frequency for treatment 5a, with 12 cm application, it was estimated that 19.0 cm or one third the water applied went to deep percolation. Deep percolation for treatment 5b with 8 cm applications (standard set time for the entire system) was estimated as 1.3 cm. With the lighter irrigations (4.0 cm) but similar intervals between irrigations, treatment 5c produced no deep percolation. For treatment 7c with 4.0 cm applications twice as often, according to the water budget analysis there was no calcualted deep percolation.

The importance of irrigation scheduling is exemplified by the difference in losses between treatments 5a, 5b, 5c, and 7c. Generally, as the depth of applied water per irrigation increases, the interval between irrigations should also be increased for a given soil water hold capacity. Even with the 18 hour set, giving 12 cm of applied water, deep percolation could be controlled if sufficient time were allowed between irrigations; but all the available water would have to be consumed between irrigations to avoid deep percolation. Availability of soil water is enhanced by irrigating more frequently

TABLE 8.11.3-2

Average Volumetric Water Content at the Beginning and End of the Irrigation Period

Treatment	Depth Interval Feet	Water Content June 5[1]	October 17
5a	0-1	13a[2]	30b[2]
	1-2	21a	34b
5b	0-1	17a	30b
	1-2	25a	33b
	2-3	25a	--
5c	0-1	11a	20b
	1-2	20a	19
7c	0-1	10a	24b
	1-2	20	25
L6[3]	0-1	16	17
	1-2	17	16
	2-3	21	--
L21[3]	0-1	15	15
	1-2	17	18
	2-2.5	19	--
Control[4]	0-1	14	13
	1-2	18	12

1/ Gravimetric technique used June 5, neutron scattering method used October 17.

2/ Values in same row followed by different letters differ at the 0.05 probability level by the T test.

3/ L refers to lateral seepage areas west of sprinkler laterals 6 and 21.

4/ Nonirrigated treatment located near sprinkler site 21.

Treatment	Irrigation Date	Amount of Water Applied (cm)	Available Soil Water After Irrigation (cm)	Consumptive[1/] Use Between Irrigations (cm)	Estimated Deep Percolation (cm)	Total Dissolved Solids (ppm)	Computed[2/] Change in Percent Soil Salt	Computed[2/3/] Change in Electrical Conductivity
5a	7-24	12.0	12.00		0	1300		
	8-9	12.0	12.00	8.00	4.00	1400		
	8-29	12.0	12.00	7.88	4.12	1500		
	9-23	12.0	12.00	7.77	4.23	1600		
	10-13	12.0	12.00	5.38	6.61	1500		
Totals		60.0		29.03	18.97		0.144	3.56
5b	7-27	8.0	8.00		0	1300		
	8-13	8.0	8.00	8.40	0	1400		
	8-22	8.0	12.00	3.55	0.45	1400		
	9-24	8.0	9.00	10.40	0	1600		
	10-11	8.0	12.00	4.76	0.84	1500		
Totals		40.0		27.11	1.29		0.094	2.38
5c	7-24	4.0	4.0			1300		
	8-13	4.0	4.0	9.97	0	1400		
	9-24	4.0	4.0	13.95	0	1600		
	10-11	4.0	4.0	4.76	0	1500		
Totals		16.0		28.68	0		0.038	0.96
7c	7-14	4.0	4.00		0	1200		
	7-24	4.0	4.00	5.17	0	1300		
	8-1	4.0	4.00	4.07	0	1300		
	8-8	4.0	4.52	3.48	0	1300		
	8-19	4.0	4.00	4.70	0	1400		
	8-28	4.0	4.65	3.35	0	1500		
	9-8	4.0	4.94	3.71	0	1700		
	9-22	4.0	4.87	4.07	0	1600		
	10-9	4.0	4.06	4.81	0	1500		
Totals		36.0		33.36	0		0.084	2.10

1/ Calculation based on Hargreaves consumptive use equation with estimates of radiation.

2/ Assuming no leaching.

3/ Assuming no precipitation or dissolution.

with less than the maximum soil water holding capacities of 12 cm. With frequent irrigations, giving a favorable soil water status near field capacity, ET will remian near the peak, depending only on the atmospheric demand. However, the practical irrigation frequency is limited by labor and scheduling considerations.

Lateral seepage outside the sprinkled areas was estimated by observing changes in the soil moisture content down slope from the irrigated area at the L6 and L21 seepage test sites indicated on Figure A8.11.3-1. The L6 and L21 data presented in Table 8.11.3-2 show little change in moisture content with time. This indicates that there was little lateral seepage from the sprinkled area.

Salt transport and accumulation are important in monitoring water percolating out of the root zone. Checking the salt balance is one method for estimating whether deep percolation has occurred in an area sprinkled with a known quality and quantity of water. The ECe would increase in proportion to the mass of salt added with the irrigation water during the season assuming dissolution and/or precipitation does not occur.

According to Richards (1954) the relationshop between the estimated change in ECe and the change in the mass of salt per unit soil mass is:

$$\Delta ECe = \frac{\Delta P_{ss} 100}{\Delta P_w \,(0.064)}$$

where

ΔEce is the change in electrical conductivity of the soil saturation extract.

ΔP_{ss} is the change in mass of salt per mass of soil expressed as a percent.

ΔP_w is the soil water content at saturation which is equal to $(1 - \frac{\text{bulk density}}{2.65})\ 100 \cong 60\%$

The mass of salt applied by irrigation, calculated from the depth of water applied over a unit area and the total dissolved salts presented in Table 8.11.3-3, is divided by the 61 cm deep soil mass in the unit area to find ΔP_{ss}. It should also be pointed out that in the calculated ECe methodology, total dissolved solids were used rather than total dissolved salts. This would tend to overestimate the calculated ECe since not all the solids are charged particles.

Soil chemical data which were taken at the beginning and end of the irrigation season are summarized in Table 8.11.3.4 for treatments 5a, 5b and 5c, and 7c. The ECe at the end of the season is practically the same in the top foot of soil as it was at the beginning of the season. However, according to the salt balance it should have increased if either leaching or precipitation had not occurred. Leaching (especially in the top foot of soil) and precipitation effects are confounded in this analysis; thus an estimate of deep percolation based on a salt balance analysis is not meaningful.

TABLE 8.11.3-4

Average of pH, Electrical Conductivity of Saturation Extract (ECe), Exchangeable Sodium Percentage (ESP), and Boron on Soil Samples Taken June 5 and December 16.

Treatment	Depth	pH -log[H] June		pH -log[H] Dec	ECe mmhos/cm June	ECe mmhos/cm Dec	ESP % June		ESP % Dec	Boron ppm June	Boron ppm Dec
5a	0-1	7.7	a*	8.4	1.0	1.1	<1	a	8.0	0.8	0.9
	1-2	--		--	0.7	--	<1		--	0.6	--
5b	0-1	7.8	a	8.3	0.9	0.8	<1	a	6.0	1.1	0.4
	1-2	7.8		--	0.7	--	<1		--	0.6	--
	2-2.5	8.1		--	0.7	--	<1		--	0.8	--
5c	0-1	7.3	a	8.2	0.4	1.0	<		5.8	0.3	0.8
	1-2	7.8		--	0.4	--	<		--	0.3	--
7c	0-1	7.9		8.4	0.6	0.6	1.8		7.8	0.7	0.6
	1-2	8.1		--	1.1	--	7.3		--	1.8	--

* Values having "a" between them differ at the 0.05 probability level by the T test.

Irrigation Scheduling

The frequency of irrigation and depth of water stored during each irrigation are closely related. Short set times giving shallow depths of applied water require frequent irrigations. A convenient set time is 12 hours with 2 sprinkler head moves per day. With 12 hour sets, 8 cm of water are applied per application. A depletion of 8 cm is 75% of the available moisture in a 2-foot (61 cm) root zone. This minimizes the labor input while maintaining high consumptive use rate without deep percolation.

Figure 8.11.3-1 gives estimates of the rate at which water can be safely disposed on a per acre basis by native vegetation under irrigated conditions at the C-b Tract sprinkler site during the 1980 season.

Monthly averages of radiation and temperature at Grand Junction coupled with temperature data from C-b Tract were used to develop the curve (see Table A8.11.3-9 for details). The gallons-per-minute figures represent the continuous (24-hr/day) gross flow rates per acre which would replenish the water consumed through ET. For example, to dispose of 440 gpm in June and July would require sprinkling approximately 115 acres but in September the system would need to be expanded to cover 220 acres (440/2.25) in order to minimize deep percolation.

Pan Evaporation Estimation

Estimates of pan evaporation can be made using available weather data in the Hargreaves equation as mentioned earlier. Appropriate constants were found in "Crop Water Requirements," published by FAO in 1975. Under climatic conditions similar to those at the C-b Tract, with strong winds, a pan surrounded by dry land, and a long fetch, the relationship between pan evaporation and consumptive use according to Hargreaves (1977) is:

$$E_{pan} = 2.07\ ET$$

where

E_{pan} is pan evaporation, cm/day
ET is consumptive use with 100% alfalfa crop cover, cm/day

An attempt was made to develop a regression equation which related E_{pan} measurements taken late in the season to ET but more than 50% of the variation was unexplained.

Soil Chemical Properties

Some salts from the applied mine water concentrated in the soil as the plants extracted water and as it evaporated from the soil surface. These can be harmful to the plants if safe tolerance levels are exceeded. The exchangeable sodium percentage (ESP), pH, and boron concentration which are presented in Table 8.11.3-4 were measured before and after sprinkling to monitor possible ion toxicity and nutrient availability. High exchangeable sodium can cause toxicity to plants as well as reduce the water infiltration capability of the soil which encourages runoff. Nutrient availability is strongly related to soil pH. Boron can cause plant damage even at low concentrations.

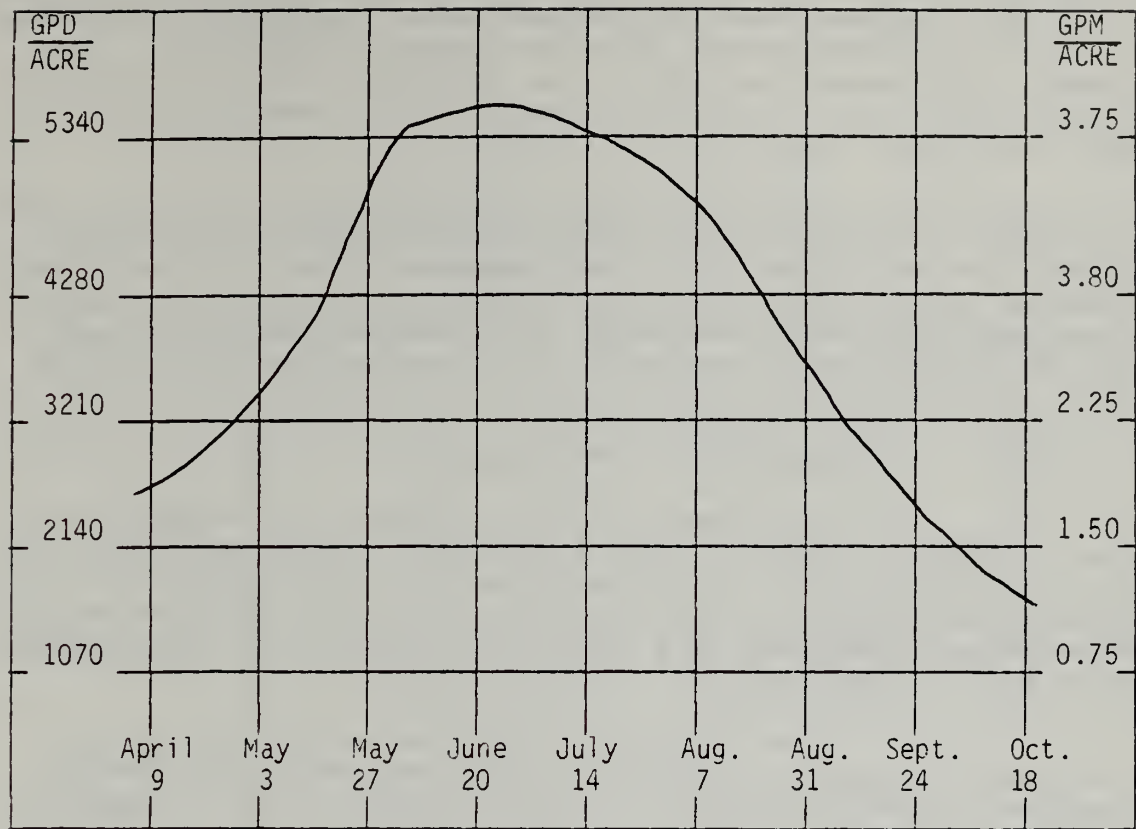


FIGURE 8.11.3-1

Simulated Gross Consumptive Use Curve at C-b Tract in Gallons Per Day Per Acre (gpd/acre) (Assuming 24 Hour Operation or Gallons Per Minute Per Acre (gpm/acre) Based on Hargreaves (1977) Equation Using 1980 Monthly Temperature and Estimated Radiation. (See Table A8.11.4-9.)

Criteria for soil nutrient availability and soil toxicity have been developed by researchers. Over the range of pH values measured in treatments 5a, 5b, 5c, and 7c, nutrients should be readily available to the plants according to Buckman and Brady (1969). Maas and Hoffman (1977) published criteria for ECe, ESP, and boron. ECe of less than or equal to 2.0 mmhos/cm may cause a slight yield reduction only in the more sensitive forage crops. Some forage crops, such as western wheatgrass, can tolerate ECe levels as high as 12 mmhos/cm with little loss in production. None of the treatments had ESP's of 10 or greater so no injury should result from sodium.

Boron concentrations greater than or equal to 2.0 ppm can cause damage to sensitive crops. Boron concentrations in all treatments were less than the harmful (or toxic) levels as shown in Table 8.11.3-4. There does not appear to be a strong relationship between the amount of water applied or treatment and the soil chemical change. Soil flouride from applied water is fixed near the soil surface; therefore, it is not available to plants for uptake.

Chemistry of the Foliage

The excess mine water applied to the vegetation during sprinkling can deposit dissolved solids on the leaves. Foliar uptake data are presented in Table 8.11.3-5 for the three cations of primary concern which are boron, sodium, and flouride. Plants are sensitive to sodium and boron and animals can be harmed by consuming large quantities of vegetation if flouride concentrations are sufficiently high.

Fluoride toxicosis was reported by Shupe, et. al. (1978) when western wheatgrass containing 60.2 ppm was consumed by livestock. Table A8.11.3-1, taken from Shupe et. al. (1978), reviews fluoride tolerance levels in water and feed.

Fluoride toxicosis in domestic and wild animals can be influenced by the following factors: (1) amount of fluoride ingested; (2) duration of fluoride ingestion (time); (3) fluctuation in fluoride intake with time (often seasonal); (4) solubility of fluoride--toxicity usually increases with solubility; (5) species of animals involved; (6) age of animal at time of fluoride ingestion; (7) general level of nutrition--malnutrition intensifies toxicity; (8) stress factors; and (9) individual biologic response according to Shupe. The tolerance levels presented in Table A8.11.3-1 can be increased under conditions of seasonal consumption and mixing with vegetation consumed in adjacent areas that does not contain fluoride.

In Table 8.11.3-5 only treatments 6b and 7c have fluoride concentrations that approach the toxic tolerance levels. Treatment 5b (Table 8.11.3-5), the standard random 12-hour set-time project treatment, is safe according to the tolerance levels presented in Table A8.11.3-1. The daytime sprinkling apparently accelerated the fluoride accumulation because treatment 6b and 7c levels were higher in all three vegetation types than the other random and night only treatments. Big sagebrush accumulated less fluoride than the grasses in every treatment.

TABLE 8.11.3-5

Average of Boron, Sodium, and Fluoride Concentrations in Foliage of Indian Ricegrass, Western Wheatgrass, and Big Sagebrush on June 5 and December 16.

Vegetation Type	Treatment	Boron ppm June 5	Boron ppm Dec 16	Sodium ppm June 5		Sodium ppm Dec 16	Fluoride ppm June 5		Fluoride ppm Dec 16
Indian	5b	92.1	29.7	24.6		657.0	3.17		10.50
Rice Grass	6b	33.4	86.1	13.8	a*	595.8	0.37	a	39.48
	7c	81.5	41.4	13.6	a	661.5	0.34	a	45.72
	8b	--	--	--		--	--		--
Western	5b	60.1	32.3	34.2	a	455.1	2.0	a	27.6
Wheat Grass	6b	22.8	47.9	94.9	a	517.5	10.8	a	41.4
	7c	41.9	29.4	45.1	a	713.3	1.4	a	45.0
	8b	71.4	41.4	37.7	a	444.1	0.4	a	32.2
Big Sage	5b	120.8	113.0	40.6	a	663.5	0.24	a	8.8
Brush	6b	50.5	106.8	61.6	a	573.2	3.0	a	16.4
	7c	79.1	138.4	1867.0		1099.2	0.37	a	18.0
	8b	225.4	101.6	60.4		803.4	0.00	a	8.56

*Values having "a" between them differ at the 0.05 probability level by the T test.

Criteria for sodium and boron in vegetation are focused on plant toxicity. According to Ehlig and Bernstein (1959) toxic foliar concentrations range from about 10 to 30 meq NaCl per 100 grams dry weight for apricot and almond trees which are very sensitive to Na and Cl and the rate of accumulation did not seem to alter the toxicity level. The converted toxicity level for sodium is 2300 to 6900 ppm Na. All the results for sodium in Table 8.11.3-5 are well below this toxic range. According to Richards (1954) boron concentrations above 250 ppm are usually associated with boron leaf toxicity. Boron levels presented in Table 8.11.3-5 are highly variable yet they are below this toxicity criterion. The highest boron concentrations were in the big sagebrush at the end of the season. No salt damage was visible during field observations.

Sodium and boron toxicities are more easily monitored because the plants will show visible signs of damage. Fluoride is more difficult to trace because the plant does not show symptoms of toxicity at levels which may be toxic to grazing animals. Because excess fluoride levels are not visible in plants and the observed levels are nearing the maximum limit, particular attention should be given to fluoride in future monitoring.

Effects from the sprinkler irrigation on herbaceous production and utilization are discussed in section 8.7.2. Effects from irrigation and fertilizer treatments on herbaceous biomass are also discussed in section 8.7.2. Effects from the sprinkler irrigation on wildlife are discussed in the appropriate sections of section 8.2.

8.11.3.6 Summary and Conclusions

Excess mine water was disposed over 100 acres of native vegetation with minimum disruption of the environment. Sprinkling using big gun sprinklers was begun in mid-July and continued to mid-October 1980. Using the information developed during the 1980 season minor system operational adjustments are recommended to minimize any adverse effects on the environment.

It was found that only minor adjustments are needed in the scheduling of irrigation to essentially eliminate deep percolation. A water use curve similar to Figure 8.11.3-1 can be used as a guide for scheduling irrigations and estimating the area necessary for disposing the excess mine water through sprinkling. However, the curve should be refined to reflect average annual conditions at the C-b Tract.

From Figure 8.11.3-1 it appears that it may be possible to use a constant average application rate of approximately 3.0 gpm/acre from mid-April through September without creating appreciable deep percolation. Thus to keep two sprinklers operating continuously for the entire period, a disposal area of approximately 150 acres (440 gpm/3.0 gpm/ac) is needed.

Soil water contents should also be checked perodically with the Hydroprobe before and after an irrigation to adjust the schedule. Irrigation is made when the soil dries below about 17% (less than 25% available water). Deep percolation can be detected by noting when water contents at maximum depths immediately following irrigation are above 35%. On the average

the available soil water storage is about 12.0 cm, thus the standard 12 hour irrigation set time which gives an application depth of 8.0 cm appears reasonable for the general project treatment without causing any deep percolation. Constant soil water content readings with time and depth downslope of the sprinkled areas indicated that there was practically no lateral seepage.

Chemical concentration levels in plant tissues and in the soil were both below their respective toxic limit ranges. However, soil boron was near the critical limit so careful observation is recommended. Soil samples should be taken about once a month in the standard treatment (when random day-night 12 hour sprinkler set times are used) throughout the season to trace boron concentrations in the soil.

Irrigation water analysis should include lists for Na, Ca, Mg, SO_4, HCO_3, B, F, Cl, TDS (total dissolved salts), EC, and pH to have the needed information for analyzing the irrigation effects on the soil chemistry. Water samples should be collected every two weeks during the irrigation season. The samples should be taken from the holding pond near the present pumping plant intake.

Fluoride levels in the tissues of some species of plants are approaching levels which would be considered toxic to animals consuming them as the continued and main source of feed. However, this would not be the case for animals migrating in and out of the sprinkled area and/or consuming a variety of plant species. Foliar fluoride concentrations should also be measured monthly in the standard treatment area as levels which may be toxic to grazing animals do not affect the plants so are not visible as in the cases of boron and sodium.

9.0 ITEMS OF AESTHETIC, HISTORIC, OR SCIENTIFIC INTEREST

9.1 Aesthetic Values

The C-b Annual Summary and Trends Report (November '74 through October '75) described a study which determined the type and quality of scenic resources in the Tract area. It was concluded that the Piceance Creek Basin has a low scenic value when compared to the other landscape types of the region. Restated, on a regional basis the Piceance Creek Basin has an extremely low visual character. However, a concerted effort has been made to paint and locate new structures to reduce any adverse aesthetic impact.

9.2 Historic and Scientific Values

A detailed baseline study of the cultural resources of Tract C-b has been conducted to identify sites of past human activity. (See Volume 1 of the Final Report of the Environmental Baseline Program.) Three historic sites exist on the Tract, (5RB136, 5RB146, and5RB147) and have been reported therein. Every site of disturbance is thoroughly investigated by the on-site environmental manager for historic or scientific value. Additional disturbance in 1980 was minimal and no additional discoveries were found.

10.0 INDUSTRIAL HEALTH, SAFETY AND SECURITY

10.1 Scope and Rationale

The health and safety of employees at the Cathedral Bluffs project is regulated according to 30 CFR, Part 57, by the Mine Safety and Health Administration under the Mine Safety and Health Amendments Act of 1977. In addition, the project is regulated by the Colorado State Division of Mines.

Periodic reports on Health and Safety Activities are forwarded to the Oil Shale Supervisor. Such reports are those prepared by the C.B. Project and all contractors for distribution to outside Federal and State agencies, i.e., Mine Safety and Health Administration (MSHA) and the Colorado Division of Mines and inspection reports made by these agencies and received by the Project and all contractors at the C.B. site. These reports relate to accident frequency analyses, inspection reports and responses, health and safety training, variance reporting, and shaft gas analysis. Inasmuch as accident frequency analysis and shaft gas analysis relate to monitoring, they are discussed below.

10.2 Accident Frequency Analysis

Table 10.2-1 presents monthly data on manhours, reported accidents (RA), lost-time accidents (LTA) and incident rate (IR) for on-site C.B. staff and contractor personnel.

Incident rate is defined as:

$$\frac{\text{Number of Accidents} \times 200{,}000}{\text{Hours of Employee Exposure}}$$

The total manhours and accident frequency rate for the year 1980 at C-b Tract are as follows:

	Manhours	Reportable Accidents	Lost Time Accidents	Incident Rate
C.B	182,617.5	3	2	3.29
Contractors	601,253	17	13	5.65
TOTAL	783,870.5	20	15	5.10 (1.91 for 1979)

10.3 Shaft Gas Analysis

Weekly average values of methane (percent) as measured at the collars of the Ventilation/Escape and Production/Service Shafts are presented in Table 10.3-1. Maximum weekly average value (0.158 percent) to date occurred in the V/E Shaft during the week of November 20-26. Maximum weekly average in the Production/Service Shafts has been 0.015 percent (December 25-30 and September 18-24).

TABLE 10.2-1

Manhours and Accident Data for Tract C-b

1980	OCCIDENTAL									CONTRACTOR									OXY & CONTR.								
	MAN HOURS			ACCIDENTS				I.R.		MAN HOURS			ACCIDENTS				I.R.		MAN HOURS			ACCIDENTS				I.R.	
	MONTH	Y.T.D	QRTR.	mon RA	ytd RA	mon LTA	ytd LTA	mon IR	ytd IR	MONTH	Y.T.D.	QRTR.	mon RA	ytd RA	mon LTA	ytd LTA	mon IR	ytd IR	MONTH	Y.T.D.	QRTR.	mon RA	ytd RA	mon LTA	ytd LTA	mon IR	ytd IR
JAN.	6,349	6,349		1	1	1	1	3.15		50,583			1	1	1	1	3.95		56,932			2	2	2	2	7.03	
FEB.	10,720	17,069		0	1	0	1	0	1.71	45,865	96,336		1	2	0	1	4.36	4.15	56,585	113,405		1	3	0	2	3.53	5.29
MAR	10,020.5	27,089.5	27,089.5	0	1	0	1	0	7.39	47,102	143,438	143,438	2	4	2	3	8.49	5.58	57,122.5	170527.5	170,527.5	2	5	2	4	7.00	5.86
APR	12,002	39,091.5		0	1	0	1	0	5.12	54,246	197,684		1	5	1	4	3.69	5.06	66,248	236,775.5		1	6	1	5	3.02	4.22
MAY	14,924.5	54,016		0	1	0	1	0	3.70	43,869	241,553		1	6	0	4	4.56	4.97	58,793.5	295,569		1	7	0	5	3.40	4.74
JUN	15,313.5	69,329.5	69329.5	1	2	0	1	13.06	5.77	46,275.5	287,828.5	287,828.5	1	7	1	5	4.32	4.86	61,589	357,158	186,630.5	2	9	1	6	6.49	5.04
JUL	17,725.5	87055		1	3	1	2	11.28	6.89	53,665	341,493.5		2	9	1	6	7.45	5.27	71,390.5	428,548.5		3	12	2	8	8.40	5.60
AUG	20,942	107,997		0	3	0	2	0	5.6	47,914	389,407.5		1	10	1	7	4.17	5.14	68,856	497,404.5		1	13	1	9	2.90	5.23
SEP	18,219.5	126216.5	126216.5	0	3	0	2	0	4.75	48,615.5	438,023	438,023	1	11	0	7	4.11	5.02	66,835	564,239.5	207,081.5	1	14	0	9	2.99	4.96
OCT	19480.5	145697		0	3	0	2	0	4.12	58,866.5	496,889.5		5	16	5	12	16.99	6.44	78,347	642,586.5		5	19	5	14	12.76	5.91
NOV	19364	165061		0	5	0	2	0	2.42	38,354	535,243.5		1	17		13	5.21	6.35	57,718	700,304.5		1	20	1	15	3.47	5.71
DEC	17,557	182618	182618	0	3	0	1	0	3.29	66,009.5	601,253	601,253	0	17	0	13	0	5.65	83,566	783,870.5		0	20	0	15	0	5.10

TABLE 10.3-1

Weekly Average Methane Readings at Shaft Collars for 1980 (%)

Date	V/E Shaft	Production/Service Shaft
3/20/80 - 3/26/80	.028%	0%
3/27/80 - 4/02/80	.037	0
4/03/80 - 4/09/80	0	0
4/10/80 - 4/16/80	.017	0
4/17/80 - 4/23/80	0	0
4/24/80 - 4/30/80	0	0
5/01/80 - 5/07/80	0	0
5/08/80 - 5/14/80	0	0
5/15/80 - 5/21/80	.004	0
5/22/80 - 5/29/80	.010	0
5/29/80 - 6/04/80	0	0
6/05/80 - 6/11/80	0	0
6/12/80 - 6/18/80	.009	0
6/19/80 - 6/25/80	0	0
6/26/80 - 7/02/80	0	0
7/03/80 - 7/09/80	0	0
7/10/80 - 7/16/80	.003	0
7/17/80 - 7/23/80	.017	0
7/24/80 - 7/30/80	.014	0
7/31/80 - 8/06/80	.023	.004
8/07/80 - 8/13/80	.023	.006
8/14/80 - 8/20/80	.054	0
8/21/80 - 8/27/80	.040	.006
8/28/80 - 9/03/80	.039	0
9/04/80 - 9/10/80	.044	0
9/11/80 - 9/17/80	.038	0
9/18/80 - 9/24/80	.024	.015
9/25/80 - 10/01/80	.054	0
10/02/80 - 10/08/80	.107	0
10/09/80 - 10/15/80	.093	0
10/16/80 - 10/22/80	.061	0
10/23/80 - 10/29/80	.058	0
10/30/80 - 11/05/80	.059	0
11/06/80 - 11/12/80	.088	0
11/13/80 - 11/19/80	.120	0
11/20/80 - 11/26/80	.158	0
11/27/80 - 12/03/80	.124	.008
12/04/80 - 12/10/80	.148	.004
12/11/80 - 12/17/80	.118	0
12/18/80 - 12/24/80	.087	0
12/25/80 - 12/31/80	.092	.015

11.0 SUBSIDENCE MONITORING

The overall objective of the subsidence monitoring program is to determine the effects of underground excavations on the ground surface and on in-situ mining levels.

The surface and underground subsidence caused by mining activities cannot start until significant underground development out from the shaft pillar areas occurs.

12.0 ECOSYSTEM INTERRELATIONSHIPS

12.1 Introduction and Scope

Indicator variables for Development Monitoring are given in the Development Monitoring Plan. Also listed are perturbations that affect the magnitude of these variables and the environmental consequences (or impacts) of these perturbations. Examples of perturbations include mining, retorting, shale disposal, waste disposal, etc. Environmental consequences may affect other indicator variables; such relations of indicator variables with other indicator variables are to be analyzed and called ecosystem interrelationships.

Ecosystem interrelationships are not monitored or measured directly. They are inferred from three principal techniques: (1) expert judgment resulting from baseline observations of two or more variables; (2) correlative statistics; and (3) predictive ecosystem modeling. Aspects of all three have been gleaned from the baseline studies and reported in Volume 5, System Interrelationships, Environmental Baseline Program Final Report and its Appendix F, User's Reference Diagrams (1977).

With regard to the comprehensive "effects matrix" so-called effect generators (driving variables, perturbations, state variables) are listed across the top (matrix columns) and effect receptors (abiotic and biotic components and processes) are listed at the side as matrix rows. Entries in the matrix are the following interrelationships: direct effects, indirect effects, both direct and indirect, and effects of particular concern. Fifty-four updated effects of particular concern have been transposed to Table 12.1-1 where they are identified with an "X".

The interrelationships of Table 12.1-1 and others defined as new monitoring results will be analyzed in the future and subjected to correlative statistical techniques as a means of defining those interrelationships of major concern. Subsequent monitoring can then concentrate on these interrelationships.

12.2 Candidate Interrelationships

The above considerations provided insights into specific interrelationship candidates for early study. The screening consisted of three phases: (1) qualitative, (2) initial quantitative, and (3) refined quantitative .

The qualitative phase consists of identifying the dependent variable(s), all major independent variables, and both natural and man-induced perturbations. Gaps in the data preclude complete quantitative analysis. However, a purpose is served in that it points the way to future increased sampling rigor and uniformity. Then, provided the data are deemed complete enough, quantitative analyses are attempted. Refined quantitative analyses may be undertaken in future years.

At this writing two candidates have passed the qualitative screen

TABLE 12.1-1

MAJOR ECOSYSTEM INTERRELATIONSHIPS

EFFECT RECEPTORS \ EFFECT GENERATORS	PRECIPITATION	AIR TEMPERATURE	BORON (Water)	SO_2 (Air)	NO_x (Air)	OZONE (Air)	FLUORIDE (Water)	TRACE ELEM. (Air)	NOISE	DISTURBED VEG.	UNREVEG. BARE AREAS	EROSION	MIXED SOIL PROFILE	ALTERED SOIL CHEM.	SEDIMENT	ALTERED SURF. WATER FLOW	WATER TABLE ALTER.	ALTERED WATER QUAL.	WIND SPEED	WIND DIRECTION	SHALE PILE	PONDS
RUNOFF	X										X	X			X							X
STREAMFLOW												X					X					
GROUNDWATER FLOW																	X					
PLANT GROWTH	X	X	X	X	X	X	X	X						X		X						
LITTER DECOMP.				X																		
ANIMAL GROWTH	X	X	X				X	X														
REPRODUCTION									X													
ANIMAL MOVEMENT									X													
AQUATIC PLANT GROWTH			X				X								X	X		X				
AQUATIC VERT. GROWTH															X	X		X				
AQUATIC VERT. MORT.																		X				
AQUATIC INVERT. GROWTH															X	X						
AQUATIC INVERT. MORT.																		X				
SOIL CHEM. & pH								X														
WATER QUALITY																	X					X
ANIMAL TISSUE							X															
GEN. HABITAT									X	X	X											
REVEGETATION													X	X								
VISIBILITY	X					X													X	X		
PARTICULATE MATTER	X																		X		X	

and initial quantitative analysis attempted. These are:
(1) The relationship between climatic variations and annual herbaceous production.
(2) The relationship between traffic on Piceance Creek Road, deer population, and deer road-kill.

Other interrelationships subjected to qualitative study included:
(3) The relationship between herbivore density and shrub utilization.
(4) The relationships between shrub production, utilization, deer migration, age/sex ratios, pellet groups, and climate, with respect to deer mortality.

Increased sampling rigor and/or uniformity may be attempted to enhance the possibility of quantitative results in the future.

These four near-term interrelationships are discussed in the following paragraphs.

12.3 Specific Near-Term Interrelationships

12.3.1 Effects of Climatic Variations on Vegetative Productivity

12.3.1.1 Scope

It is expected that vegetative productivity increases with increasing precipitation and increased length of the growing season. Specific precipitation measures are:
(1) Total annual precipitation of the current year.
(2) Total annual precipitation of the previous year, especially late season precipitation.
(3) Total annual precipitation of the previous growing season - from April through March.
(4) Precipitation temporal distribution during the growing season over:
    (a) March - April - May or
    (b) April - May - June, or
    (c) May - June - July.
(5) Abnormal rates of precipitation.

Growing-Season candidate variables include:
(1) length of the growing season,
(2) total degree-days during the growing season,
(3) degree-day temporal distribution over:
    (a) April - May - June
    (b) May - June - July
    (c) June - July - August
    (d) July - August - September
    (e) over the growing season.

12.3.1.2 Objectives

The objective in studying interrelationships is to assess the interaction between vegetation productivity, amounts and timing of precipitation, and length of growing season.

12.3.1.3 Experimental Design and Method of Analysis

It is difficult to obtain a highly accurate total of annual precipitation in a harsh, remote area at any one site, as an accumulation over a monthly or more frequent period. Often because of equipment malfunction a monthly value may be missing from the data set, such that an annual total from that station is not possible. The reader is referred to Section 6.3.1, wherein numerous between-station monthly precipitation regressions have been undertaken, e.g., between Station AB23 and microclimate stations and between Little Hills and AB23. From such regressions missing monthly precipitation values have been estimated so that annual totals can be derived. Annual totals agree reasonably with regional precipitation isohyets (Section 6.3.1). It should be further noted that precipitation in the vicinity of the Tract is spatially variable, particularly with elevation. Therefore the above qualitative suggestions on precipitation might consider not only precipitation at the meteorological tower (Station AB23) but at each of the respective microclimate stations from which vegetative productivity is potentially being correlated.

The following tables of 6.3.1 and associated appendix are useful here in this analysis:

Table or Figure	Item	Station
Table 6.3.1-3	Total Precipitation	AB23, AB20, WU70
	3 month moving average precipitation	AB23, AB20, microclimate stations
	Peak ppt events	AB23, AB20
Figure 6.3.1-3	Monthly ppt histograms with growing season superposed	AB23, AB20

This year's herbaceous productivity sites selected for analysis were:

BJ12 - Chained Pinyon-Juniper (Control Site)
BJ15 - Pinyon-Juniper Woodland (Future Development and Present Control)

All site locations are shown on Exhibit C (found in the cover jacket).

12.3.1.4 Discussion and Results

Productivity values are presented on Table 8.7.2-1 and repeated here in Table 12.3.1-1. Also tabulated are the independent variables for potential correlation: total calendar precipitation and growing-season to growing-season precipitation of the previous year, 3 month precipitation during the growing season at Station AB23 (meteorological tower) and at the microclimate station where productivity was measured, length of the growing season, and calendar year. A simple tabular approach was utilized whereby for each of the five years since Baseline productivity was ranked from highest to lowest (1 to 6 respectively) as were each of the remaining independent variables as indicated in the table.

TABLE 12.3.1-1 "RANKING" OF INDEPENDENT VARIABLES WITH PRODUCTIVITY

(1)→(6) = Rank from Top to Bottom

Site	Year	Productivity (kg/ha)	April-May-June ppt (cm) Station AB23	April-May-June ppt (cm) MC Station	Total ppt of Previous year (cm) Station AB23	Total ppt of Previous year (cm) MC Station	Total ppt of Previous Growing Season Year*(cm) Station AB23	Total ppt of Previous Growing Season Year*(cm) MC Station	Growing Season (days)
Chained Pinyon Juniper (BJ12) (Control)	1975	579 (1)	13.9 (1)	7.5 (1)	-	-	-	-	118 (4)
	1976	245 (2)	9.4 (3)	3.6 (6)	45.0 (1)	23.6 (3)	44.4 (1)	24.3 (3)	114 (5)
	1977	125 (6)	6.4 (6)	3.9 (5)	35.8 (5)	21.7 (4)	27.9 (5)	15.9 (4)	96 (6)
	1978	244 (3)	7.5 (5)	5.6 (2)	35.9 (4)	25.0 (2)	41.2 (2)	42.1 (1)	124 (3)
	1979	153 (5)	12.4 (2)	4.5 (4)	36.1 (3)	41.9 (1)	31.6 (4)	25.3 (2)	145 (2)
	1980	218 (4)	8.1 (4)	5.5 (3)	36.7 (2)	19.3 (5)	40.7 (3)	6.9 (5)	151 (1)
Pinyon Juniper Woodland (BJ15) (Future Development - Present Control)	1975	250 (1)	As Above	8.4 (1)	As Above	-	As Above	-	As Above
	1976	107 (4)		2.9 (5)		19.3 (2)		20.2 (2)	
	1977	62 (6)		0.3 (6)		10.6 (3)		6.0 (4)	
	1978	192 (2)		4.9 (2)		8.2 (5)		28.0 (1)	
	1979	84 (5)		3.3 (4)		34.1 (1)		16.6 (3)	
	1980	120 (3)		4.1 (3)		9.8 (4)		4.4 (5)	
Upland Sagebrush (BJ13) (Control)	1975	631 (2)	As Above	9.4 (1)	As Above	-	As Above	-	As Above
	1976	255 (4)		5.0 (4)		26.2 (2)		29.6 (2)	
	1977	182 (5)		3.9 (5)		23.1 (3)		13.6 (4)	
	1978	681 (1)		5.6 (2)		21.9 (4)		40.1 (1)	
	1979	468 (3)		5.4 (3)		42.2 (1)		24.5 (3)	
	1980**								
Bottomland Sagebrush (BJ14) (Control)	1975	396 (1)	As Above	8.9 (2)	As Above	-	As Above	-	As Above
	1976	154 (4)		12.8 (1)		26.3 (4)		32.0 (2)	
	1977	45 (5)		0.2 (5)		37.3 (2)		19.5 (4)	
	1978	329 (2)		5.9 (3)		32.8 (3)		64.1 (1)	
	1979	284 (3)		2.9 (4)		41.6 (1)		26.3 (3)	
	1980**								

*Total precipitation in previous year starting in April (thru March).

**No 1980 data. BJ13 and BJ14 were discontinued after 1979.

Degree-days did not correlate positively and are not shown. Quantities which rank-correlated best with productivity are precipitation during April-May-June of the current year and during the previous growing season year (the year beginning in April and ending in March). Productivity as a function of Spring and total precipitation parameters is shown on Figures 12.3.1-1a and 1b with a least squares regression line for each. All correlations were positive. The highest correlation coefficients were achieved for the previous growing season precipitation measured at the sites (BJ12 and BJ15) for which productivity was measured. High correlations were also achieved for Spring precipitation measured at the productivity sites. Some monthly precipitation values were estimated at these stations. On the basis of the slope of the regression line, chained pinyon-juniper productivity is most sensitive to growing-season rainfall at the site; when referenced to rainfall at the meteorological tower this value was significantly reduced.

12.3.1.5 Conclusions

1. Climatic parameters which correlated best with vegetative productivity were precipitation during the previous growing season year (from April through March) and Spring precipitation of the current year.
2. Chained pinyon juniper productivity was the most sensitive to growing season rainfall.

12.3.2 Effects of Deer Road Count and Traffic on Deer Road-Kill

12.3.2.1 Scope and Rationale

The specific factors assumed to influence total deer road-kill include traffic along various segments of Piceance Creek Road and weekly deer count. Interrelationships determined among these variables will be used in the formulation of mitigative measures to reduce road-kill. Annual monitoring began in mid-September and ended in May when deer migrated to the highlands.

12.3.2.2 Objectives

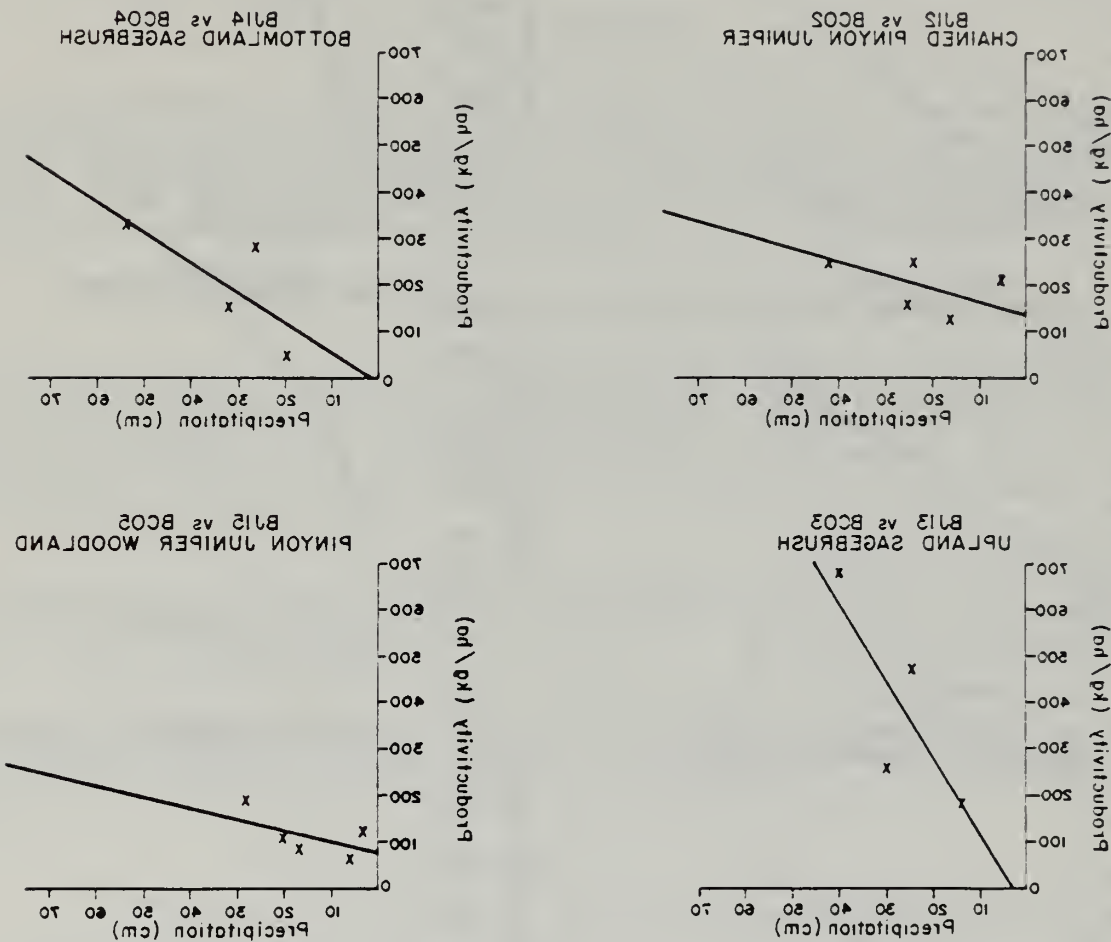
The objectives of this study are to evaluate the interrelationships of traffic load, mitigative measures, time of year, and deer population on deer road-kill; and to use information gained from study and analyses to formulate possible mitigative measures.

12.3.2.3 Experimental Design

Weekly samplings of deer road count and road-kill are obtained each year beginning in mid-September and continued through May. Tabulations are made for one mile intervals along the 41-mile stretch of Piceance Creek Road between Rio Blanco and White River City (Highway 64). Deer road-kill reports include sex of the deer killed, estimated age and marrow condition. Traffic counters are placed across Piceance Creek Road near Rio Blanco and White River City. Counters are also placed at the access road entrances to the C-b and C-a Tracts, and across Piceance Creek Road between the access roads. A count of incoming vehicles (excluding buses) is kept at the C-b

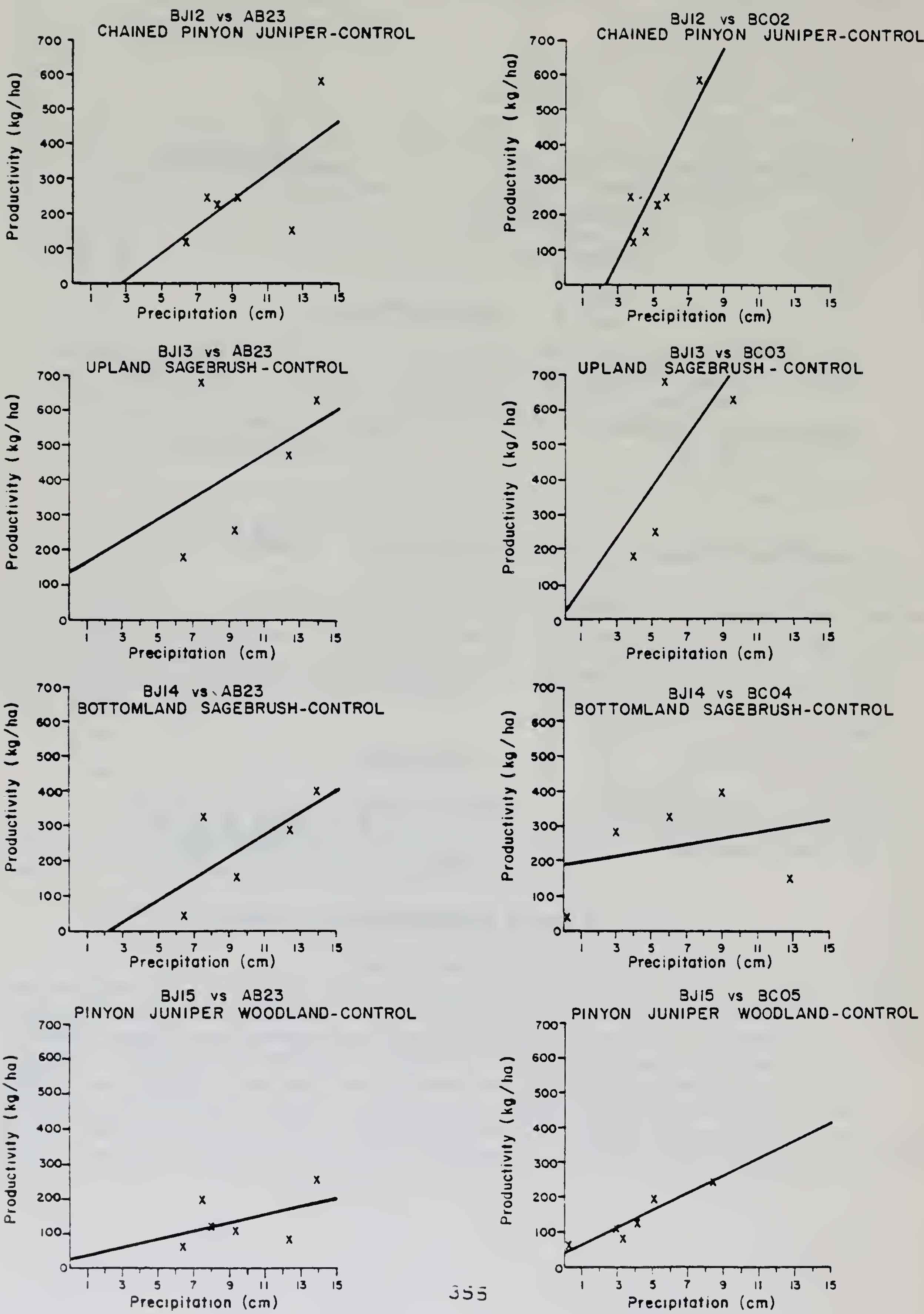
FIGURE 12-3.1-1b

PLOTS OF PRODUCTIVITY VS PREVIOUS GROWING SEASON YEAR PRECIPITATION*



* Total Precipitation in Previous Year Starting in April, (thru March)

FIGURE 12.3.1-1a PLOTS OF PRODUCTIVITY VS. APRIL - MAY - JUNE PRECIPITATION TOTALS



guard gate. In 1980, the hose traffic counters were replaced by magnetic loop counters, which provide better estimates of total traffic on Piceance Creek Road.

Passenger buses operate round trips for all work shifts between Rifle and the C-b Tract and between Meeker and the C-b Tract. Daily records of the number of passengers and number of bus trips are kept.

12.3.2.4 Method of Analysis

Data used in this study are from records beginning September 25, 1978 and ending December 31, 1980. Data were grouped and averaged to correspond with the weekly deer-kill records. Variables were examined for potential interrelationships utilizing computer programs for multiple linear regression. These programs provided analyses for evaluating statistical significance of interrelationships.

12.3.2.5 Discussion and Results

Table 12.3.2-1 is a summary of the correlations between deer road-kill and traffic and between deer road-kill and deer count. For data from September 1978 through December 1980, deer road-kill was correlated with deer count, although the regression slope was near zero. Adding vehicle count to the regression equation produced no reliable model at the 0.05 level of significance.

Data from the period of September 1979 through May 1980 produced no reliable model to relate deer road-kill with either deer count or deer count and vehicle count together.

Restricting the data set to the period from September 1980 through December 1980 provided a significant model relating deer road-kill and vehicle count. Adding the deer count to the regression produced no reliable model at the 0.05 level of significance.

12.3.2.6 Conclusion

Based on the available data, deer count was the only variable with a significant relationship to deer road-kill over all data from September 1978 through December 1980.

Deer road-kill for the time period September through December 1980 showed a significant relationship with vehicle road-count. The latter relationship implies that reduction in traffic by providing bus transportation would result in fewer road-kills during certain times of year.

12.3.3 The Effects of Herbivore Density on Shrub Utilization

The degree to which shrub production and utilization studies provide corroborative support to pellet group studies is of considerable importance, as both studies are used to monitor changes in the local deer herd. Although a one-to-one correspondence at all sites across the entire study area

TABLE 12.3.2-1

Summary of Correlation Analysis Between Deer Road-Kill and Traffic and Between Deer Road-Kill and Deer Count For Different Time Periods

Independent Variable(s)	Time Period	$\hat{\alpha}$*	r^2	Model	
				Intercept**	Slope***
X_1 Deer Count	9/78 - 12/80	0.0334	0.38	2.32	0.004
X_1 Deer Count & X_2 Vehicle Count	9/78 - 12/80	0.1098	0.38	No Reliable Model	
X_1 Deer Count	9/79 - 5/80	0.2396	0.26	No Reliable Model	
X_1 Deer Count & X_2 Vehicle Count	9/79 - 5/80	0.3918	0.37	No Reliable Model	
X_2 Vehicle Count	9/80 - 12/80	0.0396	0.80	-10.50	0.032
X_1 Deer Count & X_2 Vehicle Count	9/80 - 12/80	0.1374	0.86	No Reliable Model	

* $\hat{\alpha}$ less than 0.05 indicates a significant correlation.

** Units are Deer Road Kill.

*** Units are Deer Road Kill/Deer or Vehicle Count.

is not expected, a degree of correspondence is desirable since it strengthens conclusions regarding the causes of changes in deer herd numbers at highly localized areas of interest.

12.3.3.1 Objectives

The objectives of this study are to evaluate the interrelationships between herbivore density and shrub (browse) utilization, and to use information gained from this study to formulate possible mitigative measures.

12.3.3.2 Discussion of Qualitative Analyses

Insufficient data preclude the quantitative analysis of this interrelationship at the current time. A qualitative evaluation of production/utilization and pellet group density data is considered appropriate until data are available to perform statistical analyses.

The herbivores that contribute the most to shrub utilization are cattle, deer, and lagomorphs. Relative information on cattle densities is provided by the Bureau of Land Management (BLM) in the form of allotment management data. The number of cattle grazing on-Tract increased slightly this year over the previous four years but remains so low that the effect of cattle density on Tract shrub utilization must be considered negligible.

The experimental design of the browse production and utilization studies (Section 8.2.2) is nearly identical to that of the pellet group density studies in that the same BA-designated transects are used in each case. Deer and lagomorph pellet group studies have been previously conducted on a yearly basis as part of the Project wildlife program (see Sections 8.2.1 and 8.3.2, respectively). However, a modification in experimental design of the lagomorph studies during 1980 allows only tabulations of data from which no conclusions with regard to baseline can be drawn. Results of pellet group density studies and of the production and utilization studies were provided in Chapter 8.

12.3.3.3 Conclusions

General conclusions which can be reached at this time are:
1) Little if any correlation appears to exist in the pattern of pellet group distributions between years. One possible reason for this lack of correlation was the shift toward the pinyon-juniper habitat during the harsh winter in 1978-79.
2) The combined average for all deer pellet groups for 1979-80 was 402 pellet groups/acre, a 66 percent increase relative to the average of 242 pellet groups/acre for 1978-79.

12.3.4 Effects of Shrub Production, Utilization, Deer Migration, Age/Sex Ratios, Pellet Groups, and Climate Upon Deer Mortality

Deer Mortality (dependent variable) is influenced by many variables, but the most important ones are thought to be shrub production and utilization, deer migration, age/sex ratios, pellet groups, and climate.

12.3.4.1 Objectives

The objectives of this study are: to evaluate the interrelationships between deer mortality and variables listed above, to use information gained from this study to formulate possible mitigation measures, and to use interrelationship information to detect degree of developmental effects on deer mortality of various variables.

12.3.4.2 Discussion of Qualitative Analysis

Quantitative analyses are not possible at this time because of insufficient data, therefore analyses are qualitative. The study of interrelationships is valuable, but meaningful statistical analyses will not be possible until more data are collected.

Deer mortality data are collected on ten permanent study sites located in sagebrush draws just north of the C-b Tract. These sites were chosen after previous sampling showed the sites to be the primary winter habitat for deer associated with the C-b Tract. Also, deer mortality was greater in this area than in any other habitat. Deer mortality data have been collected since the 1977-1978 sample year (two sample periods) in the spring following winter die-off and migration to higher elevations.

12.3.5 Conclusions

General conclusions which can be reached at this time are:

1) Comparisons of deer mortality data in 1978-79 to 1979-80 data show a 57 percent increase of deer carcasses found in the 1979-80 sampling period.
2) Habitat selection by mule deer shifted towards the pinyon-juniper habitat and away from the chained pinyon-juniper habitat type in the 1978-79 and 1979-80 sampling periods.
3) Pellet group data showed a 66 percent increase from 1978-79 data to 1979-80 data.
4) Browse Production and utilization remained approximately the same as during 1979-80.

13.0 NOTES

13.1 Conversion Factors

An attempt has been made to report all studies and data in metric units*. In most cases these data are collected and initially tabulated in English units and a few analyses were carried out with English units. Table 13.1-1 contains conversion factors for converting from English to metric units. Conversion from metric to English units can be made by dividing by the factor or by multiplying by its reciprocal.

Table 13.1-2 presents additional conversion factors useful with interpretation of data reported herein.

13.2 Literature Cited

Table 13.2-1 is a bibliography of literature cited in the text. Reference in the text is by author or title.

* Hydrology is one exception.

TABLE 13.1-1

TABLE OF CONVERSION FACTORS

To Convert From	To	Multiply By
acres	ft^2	4.3560×10^4
acres	hectares	0.404687
atmospheres	$dynes/cm^2$	1.01325×10^6
atmospheres	bars	1.01325
atmospheres	mm H_g	760
atmospheres	$newtons/m^2$	1.01325×10^5
atmospheres	lbs/ft^2	2116.32
bars	atmospheres	0.98692
bars	mb	1000.00
bars	$newtons/m^2$	10^5
BTU (British Thermal Units)	gm. cal.	252.
cfm	liters/sec	0.4720
cfs	gpm	448.831
cfs	m^3/s	0 028317
degrees Fahrenheit	degrees Kelvin	(°F-32)*(5/9)+273
degrees Fahrenheit	degrees Centigrade	(°F-32)*(5/9)
degrees	radians	0.017453
feet	meters	0.3048
ft^2	$meters^2$	0.092903
ft^3/min	$m^3/sec.$	0.000472
ft^3	gals	7.481
ft^3	m^3	0.028317
gals	m^3	0.0037854
gals	liters	3.7853
gals/min	$m^3/sec.$	0.00006309
gals/min	liters/sec.	0.069088
grains	grams	0.064798918
grains	pounds	1.42857×10^{-4}
hectares	m^2	10^4
inches	cm	2.5400
$inch^3$	cm^3	16.3872
langleys	cal/cm2/min	1.000
miles	kilometers	1.60935
mph	mps	0.44703
pounds	kilograms	0.45359
pounds/acre	kg/ha	1.12173
pounds/acre	gms/m^2	0.112173
pounds/hour	grams/sec.	0.1260
$pounds/inch^2$	atmospheres	0.068046
$pounds/inch^2$	mb	68.947
radians	degrees	57.29578
rods	meters	5.0292
SCFM (Standard Cubic Ft/Min)	ACFM (Actual cubic ft/min	$(^oK_a/^oK_s)(P_s\ mb/P_a\ mb)$
ton (short)	kilograms	907.185

TABLE 13.1-2

ADDITIONAL CONVERSION FACTORS
MULTIPLES AND SUBMULTIPLES OF UNITS

Factor by Which Unit is Multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	m
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

CONVERSION FACTORS FOR GASES

Molecular Weight (MW)	Pollutant	To Convert μg/m^3 at 25°C and 760 mmHg to ppb Multiply by Factor
46.01	NO_x as NO_2	.532
30.01	NO	.815
46.01	$NO_2=NO_x$ -NO	.532
64.06	SO_2	.382
34.08	H_2S	.718
-	THC	1.530
16.01	CH_4	1.525
28.01	CO	.873
48.00	O_3	.510

Equation: $$\frac{22.414}{MW}\left(\frac{298}{273}\right) = \text{Factor}$$

TABLE 13.2-1

Literature Cited

Baumann, R. W., A. R. Gaugin and R. F. Surdick. 17. The Stoneflies of the Rocky Mountains. American Entomological Society. 208 pp.

Box, E. P. and M. Jenkins. 1976. Time Series Analysis: Forecasting and Control. 575 pp.

Buckman, H. O. and N. C. Brady. 1969. The Nature and Properties of Soils. Seventh edition. Macmillan Co., N.Y. 652 pp.

Cairns, J., Jr. and K. L. Dickson (eds.) 1973. Biological Methods for the Assessment of Water Quality. American Society for Testing and Materials special technical publication S28:1-256.

Cathedral Bluffs Shale Oil Company, Occidental Oil Shale, Inc., Operator. Development Monitoring Reports (submitted semi-annually in January and July to Oil Shale Office, Grand Junction, Colorado). Last report submitted January 15, 1980.

C-b Shale Oil Project, Ashland Oil, Inc., and Shell Oil Company, Operators. February 25, 1976. First Year Environmental Baseline Program. Annual Summary and Trends Report (November 1974 - October 15). 546 pp.

C-b Shale Oil Project, Occidental Oil Shale, Inc., Operator. 1978 C-b Annual Report. April 20, 1979.

C-b Shale Oil Project, Occidental Oil Shale, Inc., Operator. Development Monitoring Program for Oil Shale Tract C-b. February 23, 1979.

C-b Shale Oil Venture, Ashland Oil, Inc.; Occidental Oil Shale, Inc., Operator. January 15, 1978. Oil Shale Tract C-b Development Monltoring Report #1. (April 1978 - September 1978) Volumes 1-3.

C-b Shale Oil Venture, Ashland Oil, Inc.; Occidental Oil Shale, Inc., Operator. 1977. Environmental Baseline Program November 1974 - October 1976, Final Report.

Cholnoky, B. J. 1968. Die o Kologie der diatomeen in Binnengewassern. J. Cramer, Lehre, Germany. 699 pp.

Edmunds, G. F., Jr., S. L. Jensen and L. Berner. 1976. The Mayflies of North and Central America. Univ. of Minn. Press. 330 pp.

Emlen, J. T. 1971. Population Densities of Birds Derived from Transect Count. Auk 88: 323-342.

Gray, L. J. and J. V. Ward. 1978. Environmental Effects of Oil Shale Mining and Processing Part II - the Aquatic Macroinvertebrates of the Piceance Basin, Colorado, Prior to Oil Shale Processing. U.S. Environmental Protection Agency. EPA-600/3-78-097. 40 pp.

TABLE 13.2-1 (Continued)

Literature Cited

Hutchinson, G. E. 1975. A Treatise on Limnology. Vol. III Limnological Botany. John Wiley and Sons, New York. 660 pp.

Hynes, H. R. N. 1970. The Ecology of Running Waters. University of Toronto Press. Suffolk, Eng. 555 pp.

Kolkowitz, R. and M. Marsson. 1909. Ecology of Animal Saprobia. Int. Rev. Hydrobiology and Hydrogeography. 2:126-153.

Linhart, S. C. and F. F. Knowlton. 1975. Determining the Relative Abundance of Coyotes by Scent Station Lines. Wildl. Soc. Bull. 3:119-124.

Lloyd, M. and R. J. Ghelardi. 1964. A Table for Calculating the "Equitability" Component of Species Diversity. Journal of Animal Ecology 33:217-255.

Lowe, R. L. 1974. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. U.S. Environmental Protection Agency. Environmental Monitoring Series. EPA-670 4-74-005. 334 pp.

Margalef, R. 1967. Information Theory in Ecology (translated by W. Hill), General System. 3:36-71.

Martinson, R. J. 1980. Macroinvertebrate Community Structure of Springbrook Habitats in the Piceance Creek, Colorado. Unpub. M.S. Thesis, Colorado State University. 89 pp.

Maxwell, E. L., R. M. Aherron, D. Fitz, G. Gross, J. Grunblatt, and A. Morse, "Monitoring Drought Impact from Landsat." Contract #NAS5-25081 (NASA/GSFC). 1980.

Maxwell, E. L. and J. Grunblatt. "Use of Landsat Digital Data in Assessing Vegetation Change, Condition, and Its Changes near the C-b Tract in the Piceance Basin of Northwestern Colorado." Contract to C.B. Project, Colorado State University Research Inst., Fort Collins, Colorado, March 7, 1980.

Oil Shale Tract C-b, Detailed Development Plan and Related Materials, Vol. II, Prepared for Submittal to the Area Oil Shale Supervisor Pursuant to Lease C-20341 issued under the Federal Prototype Oil Shale Leasing Program, Ashland Oil Inc., Shell Oil Company Operator, February 1976.

Patrick, R. 1977. Ecology of Fresh Water Diatoms - Diatom Communities. IN: The biology of diatoms. D. Werner (ed.). Univ. of Calif. Press. Berkeley, California. 498 pp.

Pennak, R. W. 1978. Fresh-water Invertebrates of the United States. 2nd ed. John Wiley and Sons, Inc., New York. 803 pp.

TABLE 13.2-1 (Continued)

Literature Cited

Pielou, E. C. 1966. The Measurement of Diversity in Different Types of Biological Collections. Jour. Theoretical Biology. 13:131-144.

Sellers, W. D. 1970. Physical Climatology. University of Chicago Press. 272 pp.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Iowa State Univ. Press, Ames, Iowa. 593 pp.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co. Publishers, San Francisco. 776 pp.

Usinger, R. L. (ed.). 1956. Aquatic Insects of California. Univ. of Calif. Press, Berkeley, California. 508 pp.

Ward, J. V. and R. G. Dufford. 1979. Longitudinal and Seasonal Distribution of Macroinvertebrates and Epilithic Algae in a Colorado Springbrook-Pond Ecosystem. Arch-Hydroboil. 86(3):284-321.

Water Augmentation Plan (WAP), a stipulation in Court Decree as approved by Judge Lore in Case No. W-3493, District Court in and for Water Division No. 5, State of Colorado. April 20, 1979.

Weber, C. I. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. U.S. Environmental Protection Agency. Environmental Monitoring Series. EPA-670/4-73-001.

Whitton, B. A. (ed). 1975. River Ecology. Univ. of California Press, Berkeley, California. 725 pp.

Zar, Jerrold H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 1974, 620 pp.